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The Effects of Schema-Based Intervention on the Mathematical Word Problem Solving Skills of Middle School Students with Learning Disabilities

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The Effects of Schema-Based Intervention on the Mathematical Word Problem Solving Skills of Middle School Students with Learning Disabilities

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Dedication

To my family:

My dearest parents, my husband, and my children

for their support and prayer.

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The Effects of Schema-Based Intervention on the Mathematical Word Problem Solving Skills of Middle School Students with Learning Disabilities

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A schema-based instruction allows students to approach a mathematics problem by focusing on the underlying semantic or problem structure, thus facilitating conceptual understanding and adequate skills. The purpose of this study was to examine the effectiveness of schema-based intervention on the mathematical word problem solving skills of middle school students with learning disabilities in grades 6 and 7.

A nonconcurrent multiple baseline design was used for the study. Four middle school students with learning disabilities participated in pre-experimental (i.e., introduction, screening test, and Mathematics Interest Inventory sessions) and experimental (i.e., baseline, intervention, post-intervention test with generalization test, and maintenance test) sessions over a 13-week period. Participants were randomly assigned to a priori baseline durations (i.e., 6, 9, 12, 17 days) (Watson & Workman, 1981). During the intervention phase, students received 12 sessions of individual 30-35 minute schema-based intervention for 6 days (i.e., 2 sessions per day). Students participated in guided and independent practice and were encouraged to ask questions as they worked to master the material taught in each intervention session. During the post-intervention phase, the four students' accuracy performance was evaluated by six untimed achievement or generalization tests. The achievement and generalization tests contained a total of 10 one-step multiplication and division word problems. All of the students achieved scores greater than a pre-determined criterion level of 70% accuracy on the six consecutive tests. Two weeks after termination of the post intervention phase, each student's accuracy performance on the achievement and generalization tests was examined during the follow-up maintenance phase.

Findings revealed that the four students' performance substantially improved after they received the intervention. All four students achieved scores that exceeded the criterion level (70% accuracy) on the achievement tests during the post intervention phase. These findings provide empirical evidence that schema-based intervention is effective in teaching middle school students with learning disabilities to solve multiplication and division word problems. Limitations of the research and implications for practice and future research are discussed.

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CHAPTER 1

INTRODUCTION

Reform efforts in mathematics education were spurred by the *Principles and Standards for School Mathematics* (or the *Standards*), which were developed by the National Council of Teachers of Mathematics (NCTM, 1989, 2000). The *Standards* prompted changes in teacher preparation programs and mathematics curriculum and instruction towards standards-based reform in mathematics education (Rivera, 1998). A key focus of this reform was an emphasis on conceptual understanding and reasoning rather than rule-driven memorization (Maccini & Gagnon, 2002; NCTM, 2000). In particular, since the NCTM identified problem solving as a central theme in the *Standards* (NCTM, 1989, 2000), this area has received considerable attention in the literature (e.g., Chen, 1999; Jitendra, Griffin, Deatline-Buchman, DiPipi-Hoy, Sczesniak, Sokol, et al., 2005; Maccini & Gagnon, 2002; Mayer & Hagarty, 1996; Miller & Mercer, 1993; Parmar, Cawley, & Frazita, 1996; Woodward, Monroe, & Baxter, 2001; Xin, & Jitendra, 1999; Xin, Jitendra, & Deatline-Buchman, 2005). Researchers have indicated that solving an array of seemingly different, but structurally similar problems will promote the development of generalized problem solving skills and schema knowledge (Chen, 1999; Mayer & Hagarty, 1996). However, students were not provided this type of experience with traditional mathematics problem solving instruction (Parmar et al., 1996). Teachers traditionally focused on the simple memorization of rules, key words or specific steps (e.g., Jitendra et al., 2005; Parmar et al., 1996; Woodward et al., 2001).

Students with LD in Mathematics

Approximately 5-8% of school-age students have deficits in mathematical skills (Geary, 2004). Although the prevalence of mathematical learning disability is comparable to the prevalence of reading disability, there has been less research about mathematical learning disability comparatively (Jordan, Levine, & Huttenlocher, 1995; Mazzocco & Myers, 2003). In part, the complexity associated with the study of mathematics may cause this discrepancy (Landerl, Bevan, & Butterworth, 2004). Because a learning disability (LD) is defined in a complex relationship to many mathematical domains and individual competencies within each domain, the challenge of understanding mathematical learning disability has resulted in less research focused on this area (Geary, 2004). However, a growing body of research has contributed to indicate that mathematics learning disability (MLD) in calculation and word problem solving is a recognized type of learning disability (Individuals with Disabilities Education Improvement Act, 2004; Bryant, Bryant, Gersten, Scammacca, & Chavez, 2008)

Successful mathematics performance is considered important to educational and occupational opportunities and most secondary schools require that all students take higher level mathematics to graduate (Chambers, 1994). However, students with LD experience more difficulties than their peers without LD. For instance, although a major emphasis of secondary school mathematics curricula is problem solving (Dossey, Mullis, Lindquist, & Chambers, 1988), students with LD frequently lack essential general problem solving skills and domain specific knowledge. They also exhibit deficits in executing specific mathematical strategies and fail to use self-regulation (Pressley, Symons, Snyder, & Cariglia-Bull, 1989). In addition, many students with LD in secondary schools experience difficulty in the performance within specific mathematics area (e.g., algebra), which requires knowledge of basic skills and terminology, problem representation, problem solution, and self-monitoring (Maccini & Hughes, 2000). Thus, it is critical that secondary students with LD are provided with facilitating interventions that promote success in secondary mathematics and provide preparation for post-secondary opportunities.

Mathematical Word Problem Solving and Students with LD

Verschaffel, Greer, and De Corte (2000) defined word-problems as "verbal descriptions of problem situations wherein one or more questions are raised to obtain the answer by the application of mathematical operations to numerical data available in the problem statement (p. ix)." According to this definition, two features of word-problems are included. One is the use of words to describe a situation (e.g., A man has to be at work by 9:00 a.m. and it takes him 15 minutes to get dressed, 20 minutes to eat and 35 minutes to walk to work. What time should he get up?), and the other is the description of mathematical tasks (e.g., Add up the time required, and subtract this time from the time he has to be at work, Verschaffel et al., 2000). Baroody (1987) advocated that problem solving instruction should include the following types of problems: (a) problems that require analysis of the unknown; (b) problems that provide too much, too little, or incorrect data; (c) problems that can be solved in more than one way; (d) multistep problems; (e) problems with more than one correct answer; and (f) problems that require an extended effort. However, verbally stated numerical problems are not considered word-problems (e.g., What number do you obtain when you multiply 12 by 3?) because a word-problem should refer to a real-life context (Semadeni, 1995).

Word-problems in mathematics are challenging for many students because of the complexity of the problem solving process (Jonassen, 2003; Miller & Mercer, 1993; Schurter, 2002). Furthermore, students with LD have significantly more difficulty in solving math word-problems than their peers without LD (Cawley & Miller, 1989; Montague, & Applegate, 1993). Specific problem solving behaviors distinguish successful problem solvers from poor problem solvers (Mayer, 1999). For example, successful problem solvers (a) quickly and accurately identify the mathematical structure of a problem that can be generalized across a wide range of similar problems, (b) remember a problem's structure for a long time, and (c) distinguish relevant from irrelevant information (Quilici & Mayer, 1996). In addition, successful problem solvers tend to engage a variety of strategies (e.g., drawing pictures or diagrams, identifying important parts, disregarding extraneous information, rereading) to represent and solve word-problems (Montague, 1988; Montague & Applegate, 1993; Montague, Warger, & Morgan, 2000).

In contrast to successful problem solvers, students with LD may exhibit qualitatively different strategies when they employ cognitive and metacognitive strategies, which result in difficulty with problem-representation and solution (Montague & Applegate, 1993). Although students with LD have been observed to reread problems, they appeared to have difficulties translating information into mathematical equations despite a positive attitude toward mathematics (Parmer, 1992; Hutchinson, 1993;

Montague & Applegate, 1993; van Garderen & Montague, 2003). Unsuccessful problem solvers tend to focus on the surface features of a problem, making it difficult for them to transfer their learning to a wide range of structurally similar problems, whereas successful problem solvers seek and find underlying structural information (e.g., problem schemata) (Silver & Marshall, 1990). Therefore, providing problem solving opportunities and instruction that emphasize mathematical thinking and reasoning is important in order for students with LD to acquire conceptual understanding of fundamental math concepts and principles.

Mathematical Word Problem Solving Interventions

Word-problem solving interventions for students with LD may be categorized as including task variation, computer-assisted instruction (CAI), cognitive/metacognitive strategy intervention, and schema-based intervention (SBI). First, task variation refers to manipulation of word-problem tasks (Jitendra, & Xin, 1997). Effective word-problem solving intervention may be influenced by structured presentation sequence or word-problem format (Bottage & Hasselbring, 1993; Miller & Mercer, 1993; Wilson & Sindelar, 1991). For example, word-problem solving intervention may be sequenced such that easy skills are taught before more difficult ones, to reduce student errors and frustration (Silbert, Carnine, & Stein, 1990). That is, this type of intervention entails presenting the relatively simple or concrete level of story problems first, and then working on the more complex or abstract level of problems that require advanced cognitive processing (Jitendra, & Xin, 1997). Second, CAI refers to an interactive instructional method that uses a computer to present material, track learning, and direct the user to additional material that meets the student's needs (Okolo, 1992). Some studies (e.g., Gleason, Carnine, & Boriero, 1990; Shiah, Mastropieri, Scruggs, & Fulk, 1995) indicated that CAI was either equivalent to teacher's instruction or beneficial for students with mild disabilities. Other studies demonstrate that certain curricular and instructional software design features are found to be critical in successfully using CAI to teach word-problem solving (Babbitt & Miller, 1996).

Cognitive/Metacognitive Strategy Intervention

Another group of researchers have shown the use of cognitive/metacognitive planning and schema strategies to be very effective in helping students with learning disabilities enhance their mathematics word problem solving skills. Metacognition consists of both knowledge and awareness of one's cognitive strengths and weaknesses and self-regulation skills to coordinate this awareness with appropriate actions (Wong, 1999). Both the ability to select appropriate strategies and self-regulation are needed to solve problems successfully (Wong, Harris, Graham, & Butler, 2003).

Cognitive/metacognitive strategy intervention may include diagrams, but the emphasis is placed more on problem solving heuristic procedures that lead to a solution with self-regulation rather than on identifying the semantic relations in a problem (Jitendra, DiPipi, & Perron-Jones, 2002). In this intervention, students with LD are taught to be able to guide themselves through the process of solving word-problems by using self-regulation strategies, which include self –verbalization, self-questioning, and self-evaluation (i.e., Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague, Warger, & Morgan, 2000). For example, Montague and her colleagues examined the effects of cognitive/metacognitive strategy instruction on the students' ability to solve word problems (i.e., Montague, 1992; Montague et al., 1993). Three treatment conditions of cognitive strategy only, metacognitive strategy only, and the combination of cognitive-metacognitive strategy intervention were provided to teach students to solve one-, two-, and three-step word-problems. In the first cycle of treatment, cognitive strategy only or metacognitive strategy only was provided followed by intervention in the complementary component of the interventional program in the second cycle so that all subjects eventually received both cognitive strategy intervention and metacognitive strategy intervention. Specifically, for the cognitive strategy treatment, students learned only the names of the processes and their descriptions (i.e., read to understand, paraphrase – putting the problem in their own words, visualize – with a picture or a diagram, hypothesize – make a plan to solve the problem, estimate – predict the answer, compute – do the arithmetic, check – make sure everything is right). As part of strategy training, students were required to memorize the seven step processes. For the metacognitive strategy treatment, only the metacognitive activities associated with each cognitive process (i.e., saying, asking, and checking activities) were taught. In these two treatment conditions, both modeling and corrective feedback were provided.

Schema Based Intervention

Schema is a general description of a group of problems that share a common underlying structure and require similar types of solutions (Chen, 1999; Gick & Holyoak, 1983). Schema theory is the theoretical basis for a major contrasting approach to cognitive/metacognitive strategy intervention that has been developed in the research literature as an alternative way to teach word-problem skills to students with learning difficulties (Fuchs, Seethaler, Powell, Fuchs, Hamlett, & Fletcher, 2008). To teach schema understanding, four separate but interrelated problem solving procedural steps may be employed. The four steps are problem schema identification (or schema knowledge), representation (elaboration knowledge), planning (strategic knowledge), and solution (execution knowledge) (Marshall, 1995; Mayer, 1999). The effectiveness of mathematics instruction in word problem solving may be influenced by whether or not the instruction explicitly focuses on the semantic structure of word-problems (e.g., Fuchs, Fuchs, Fineli, Courey, & Hamlett, 2004; Hutchinson, 1993; Jitendra et al., 2002; Jitendra, Griffin, McGoey, Gardill, Bhat, & Riley, 1998; Xin et al., 2005; Zawaiza & Gerber, 1993). A schema-based instruction allows students to approach the problem by focusing on the underlying semantic or problem structure, thus facilitating conceptual understanding and adequate skills (Marshall, 1995).

When teaching the problem structure, a diagram is used as a representation that shows the parts of a math word-problem and how they are related (Diezmann & English, 2001). Generating a representation such as a diagram involves understanding the meaning of the text, translating that information into a representation that highlights the quantitative features of a problem, and developing an understanding of the important quantitative relationships among the individual statements (Geary, 1996). Instruction using a diagram includes three parts: conceptual understanding of diagrams, how to generate diagrams, and using diagrams to problem solve (Diezmann & English, 2001). Proficient problem solvers have been reported to make a diagrammatic representation of the problem between initial problem comprehension and the development of an equation or number sentence (Walker & Poteet, 1989-90). Since students with mathematics disabilities commonly fail to connect the use of a strategy to the process of solving mathematical word-problems, how to use diagrams as a part of the problem solving performance needs to be clearly demonstrated (Walker & Poteet, 1989-90).

As a method to teach problem structure, Jitendra and her colleagues employed schema-based instruction to enhance word problem performance among middle school students with learning difficulties (i.e., Jitendra et al., 2002). In this study, problem-schema identification was provided followed by a problem-solution instruction. Students learned to identify the key problem features and map the information onto the diagram during the intervention. In the first phase, story situations with no unknown information were presented to provide students with a complete representation of the problems with unknown information. In this phase, intervention emphasized checking the accuracy of the representation by having students transform the information in the diagram into a meaningful mathematics equation. In contrast, the problem-solution instruction phase used story problem with unknown information that students were taught to use a question mark to flag.

Favorable acquisition and maintenance effects were achieved through both the cognitive/metacognitive strategy intervention and the schema-based intervention. Although both interventions rely on schema theory and diagrams are used as methods, schema-based intervention differs from the metacognitive approach in that in schema-based interventions similar underlying mathematical structures and problem-solving rules for each problem type are taught explicitly by grouping problems into types (Fuchs et al., 2008).

Statement of the Problem

Schema acquisition is a fundamental component of skilled problem solving performance (Didierjean & Cauzinille-Marmeche, 1998; Fusion & Willis, 1989; Sweller, Chandler, Tierney & Cooper, 1990). Through acquiring schema knowledge by solving an array of seemingly different, but structurally similar problems, students will be able to develop their generalized problem solving skills (Chen, 1999; Mayer & Hegarty, 1996). Despite the research demonstrating the importance of schema acquisition in enhancing word-problem solving skills, students are not usually provided this type of experience in traditional mathematics problem solving instruction, which focuses only on the simple memorization of rules, key words and steps (Parmar et al., 1996).

In addition, according to two literature reviews (Jitendra & Xin, 1997; Rivera, Smith, Goodwin, & Bryant, 1998) and a meta-analysis (Xin & Jitendra, 1999), which documented the effectiveness of word-problem solving interventions on performance in mathematics, emphasizing semantic and problem structure understanding using schematic diagramming is more effective than other strategies such as key word instruction, sequencing instruction only, or metacognitive instruction only. The effects of the schema based intervention on the mathematical word problems solving skills of students with LD have been clearly shown during the last decade. However, studies that employed schema based intervention failed to control students' reading levels and suggested that further research is needed to investigate the effects of using these instructional strategies while controlling for students' reading skills (i.e., Jitendra et al., 2002; Xin et al., 2005). The failure to control for students' reading level made the results of the studies unclear because reading comprehension is an important contributing factor to students' word problem solving performance (Zentall & Ferkis, 1993). Therefore, the purpose of the current study was to investigate the effectiveness of schema based intervention specifically on the ability of students with LD whose IEPs had goals for mathematics.

Significance of the Study

This study is expected to contribute to the literature in mathematics instruction for students with LD as this study extends the existing body of research regarding the applicability of the schema strategy in promoting word problem solving skills in middle school students with LD (i.e., Jitendra et al., 1999; Jitendra et al., 2002; Xin et al., 2005). Specifically, this study provided students with real world problems developed by using the Mathematics Student Interest Inventory (Allsopp, Kyger, Lovin, Gerretson, Carson, Ray, 2008). Second, this study explored the effects of schema-based intervention on the ability of students with learning difficulties to solve one-step multiplication and division word problems as the existing studies have done, but included only students with LD who had goals in mathematics on their IEP and whose reading levels suggested that they had reading skills to understand mathematics word problems.

Purpose of the Research

The purpose of this study was to examine the effectiveness of schema-based intervention on the mathematical word problem-solving skills of middle school students with LD in grades 6-7.

Research Questions

Four research questions guided this study: (a) To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after a schema-based intervention?; (b) To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed by using the Mathematics Student Interest Inventory (Allsopp et al., 2008)?; (c) To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy for solving multiplication and division word problems?; (d) How will students with LD in grades 6-7 evaluate the effectiveness and acceptability of schema-based intervention?

CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this chapter is to review the literature on mathematical word problem solving for students with mathematics difficulties. Since developing students' problem-solving skills has been a major objective in mathematics education reform (NCTM, 1989, 2000), a number of studies have been conducted on the mathematical word-problem-solving performance of students with mathematics difficulties (i.e, Bottage, & Hasselbring, 1993; Case, Harris, & Graham, 1992; Cassel & Reid, 1996; Fuchs et al., 2004; Gleason et al., 1990; Hutchinson, 1993; Jitendra et al., 2002; Jitendra & Hoff, 1996; Jitendra et al., 1999; Jitendra & Xin, 1997; Maccini & Hughes, 2000; Montague, 1992; Montague et al., 1993; Moore & Carnine, 1989; Shiah et al., 1995; Walker & Poteet, 1989-90; Xin et al., 2005; Zawaiza & Gerber, 1993). These studies showed clear evidence that students with mathematics difficulties need to be provided with effective strategy instruction before they can solve mathematical word problems successfully. A number of intervention studies have employed cognitive/metacognitive strategy instruction (e.g., Case et al., 1992; Montague, 1992; Montague & Bos, 1986; Montague et al., 1993), and schema-based instruction (e.g., Hutchinson, 1993; Jitendra et al., 2002; Jitendra et al., 1999; Xin et al., 2005). According to the result of several syntheses (i.e., Xin & Jitendra, 1999; Na, 2007); however, schema-based instruction has shown more potential benefits in teaching mathematics problem solving to students with mathematics difficulties. In addition, Fuchs and her colleagues showed the benefit of schema based intervention in teaching third grade students to solve novel problems by using learned problem solution rules (Fuchs et al., 2004). Recently Jitendra, a major contributor to the literature on schema-based instruction, published a book containing teaching scripts and materials based on the knowledge she accumulated from the studies she has done with her colleagues (i.e., Jitendra, 2007).

As the purpose of this study is to examine the effectiveness of schema-based intervention on the mathematical word problem-solving skills of middle school students with LD in grades 6-7, this chapter will present three related bodies of literature: (a) cognitive characteristics of students with Mathematics Learning Disability (MLD); (b) procedures for word problem solving, and (c) schema-based intervention.

Characteristics of Students with Mathematics Learning Disability

Different students have difficulties in learning mathematics for different reasons (Geary, 1994). Students who have been identified as having a learning problem in mathematics may perform poorly because of a lack of experience, poor motivation, or anxiety (Geary, 2004). However, both the cognitive and neuropsychological studies on MLD conclude that one or more underlying cognitive or neuropsychological deficits negatively affect mathematical performance (e.g., Geary, 1990, 1993, 2004, 2005; Geary, Brown, & Samaranayake, 1991; Geary, Hamson, & Hoard, 2000; Jordan, Hanich, & Kaplan, 2003; Montague & Applegate, 1993; Murphy, Mazzocco, Hanich, & Early, 2007). The various cognitive components are procedural and fact-retrieval skills, conceptual knowledge, working memory, and visuospatial skills.

Procedural and Fact-retrieval skills

Two detailed cognitive studies of students with MLD were conducted by Geary and his colleagues (i.e., Geary 1990; Geary et al., 1991). In the first groups of students with MLD and typically achieving children in the first grade were administered a cognitive addition task. The three groups of students (i.e., normal, MLD-improved, and MLD-no change) were administered a cognitive addition task at the end of first grade. The MLD children were placed into two groups: those who showed improved mathematics skills from the end of kindergarten to the end of first grade and those who showed no relative change in mathematics skills.

Children in all three groups used the same types of problem solving strategies (i.e., retrieval, verbal counting, and counting fingers) to solve simple addition problems. They differed in their performance in terms of the skill and speed of executing the strategies but the MD-improved and normal children did not differ substantively in the skill or speed of executing any of the strategies. This result suggests that the MD-improved children were cognitively normal and apparently were misidentified (Geary, 1990). In comparison with the two other groups, the MD-no change group performed with a high frequency of procedural (i.e., counting procedures) and fact-retrieval errors showed frequent use of immature counting, and had great variability in the speed of executing the counting and retrieval strategies. In other words, the patterns of time taking for solving problems requiring fact retrieval were not consistent in relation to the pattern that is found with academically typical children.

About ten months later, a follow-up study of these students was conducted (i.e., Geary et al., 1991). In this study, the performance of the normal and MD-improved students showed an increased reliance on fact retrieval and a decreased reliance on counting to solve addition problems. These children also were faster at executing both types of strategies at the end of second grade. The MD-no change students, on the other hand, showed no change in the number of facts that they could remember and made eight times as many fact-retrieval errors as did the normal children (i.e., 16% vs. 2%, respectively). These studies suggest that first-grade MD children have poor procedural skills and unsystematic representation of the problems, and that developmental trend of the MD-no change students was different from that of the other groups (Geary, 1990; Geary et al., 1991).

Conceptual Knowledge

Poor performance by students with MLD in the adoption of procedures and detection of procedural errors can be due to a poor understanding of the concepts underlying a procedure (Ohlsson & Rees, 1991). In one study (i.e., Geary, Bow-Thomas, & Yao, 1992), two groups of students (i.e., MLD and typically achieving) in the first grade were administered a series of counting tasks that were designed to assess their understanding of the three how-to-count principles (i.e., stable-order principle, one-to-one principle, and cardinality principle; Gelman & Meck, 1983). All students were also administered a cognitive addition task and assessed in their understanding of the essential and some of the unessential features of counting (Briars & Siegler, 1984). On the tasks, the students with MLD committed more than twice as many counting-procedure errors as did the normal children and were more likely to use the counting-all, instead of the counting-on procedures. The children with MLD also retrieved fewer facts from memory, and when they did remember an answer, it tended to contribute to increase in the error rate (i.e., 66% error rate). The performance of these students on the counting tasks suggested that immature understanding of a certain concept (i.e., the essential and unessential features of counting) contributed to their poor performance. In other words, the delayed use of procedural skills of many students with MLD might be due to an immature understanding of the associated concepts such as order irrelevance (Geary et al., 1992; Geary et al., 2000).

Working Memory

Many research studies have shown that students with MLD do not perform as well as their academically normal peers on working memory tasks (Geary et al, 1991; Geary et al., 2000; Siegel & Ryan, 1989; Murphy et al., 2007; Swanson, 1993). For instance, in a recent study, Murphy and her colleagues (2007) assessed the characteristics of children with MLD based on varying MLD definitions of mathematics performance, either below the 10^{th} percentile (n = 22) or between the 11^{th} and 25^{th} percentile (n = 42) on the *Test of Early Math Ability*. In this study, the *Contingency Naming Test* (CNT ; Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002) was administered as a measure of executive function of working memory and reactive flexibility. The CNT is composed of two subtests which require naming stimuli according to a one- or two-attribute contingency rule. On the CNT, children without MLD were more efficient at completing both the one and two-attribute working memory tasks than were children with

MLD. There were also differences between efficiency scores for the non-MLD group and the MLD group. This result suggested that students with MLD are not as skilled as other students in retaining information in working memory.

Visuospatial skills

Visuospatial skills in mathematics learning and achievement are defined as mental skills related to understanding, manipulating, reorganizing, or interpreting relationships visually (Tartre, 1990). Spatial visualization tasks require manipulating information with those skills. Students with learning problems in mathematics exhibit visual-spatial difficulties, which contribute to poor mathematical performance (Garnett, 1992). Research has suggested that any deficits in these skills could result in MLD (Geary et al. 2000; Hanich, Jordan, Kaplan, & Dick, 2001; McLean & Hitch, 1999). As a result of these deficits, students with MLD might have problems executing complex mathematical procedures due to information-processing difficulties (Miller & Mercer, 1997). Difficulties in the spatial representation of numerical information and in some conceptual difficulties (e.g., understanding place value) can be due to a visuospatial form of MLD (Schloss, Smith, & Schloss, 1990). For instance, children with visuospatial deficits often have problems putting the columnar information in the correct position when solving multicolumn addition problems (Schloss et al., 1990). Structuring the written form of such problems was suggested, to reduce the frequency of columnar errors (Schloss et al., 1990).

At this time, the relation between visuospatial competencies and MLD has not been thoroughly explored (Geary, 2004), and further research is necessary to examine how the visuospatial skills of children with MLD are related to the other types of cognitive deficits (Geary et al., 2000; Jordan et al., 2003).

Relationship between Reading Disabilities and Mathematical Disabilities

A series of research studies have shown that mathematics performance and reading skills are closely related and that difficulties in reading and mathematics often co-occur for children with LD (i.e., Fuchs & Fuchs, 2002; Geary et al., 2000; Jordan et al., 2003; Jordan, & Montani, 1997; Silver, Pennet, Black, Fair, & Balise, 1999). For example, Jordan et al. (2003) examined four achievement groups (i.e., MD-only, difficulties in mathematics but not in reading; MD-RD, difficulties in mathematics as well as in reading; RD-only, difficulties in reading but not in mathematics; and NA, normal achievement in mathematics and in reading) in a two-year longitudinal study. They found that second graders with MD-only had a different profile from children with MD-RD on cognitive variables related to mathematics competence. In particular, MD-only children performed better than MD-RD children on mathematics tasks that have a basis in language but not on those that rely on numerical understanding (e.g., numerical magnitudes). They also found that RD predicted children’s progress in mathematics, but MD did not affect children’s progress in reading; moreover when demographic factors were held constant, the MD-only group progressed at a faster rate in mathematics than the RD-only group. The groups progressed equally quickly in reading.

Various approaches have been used to study the relationship between MD and RD. For example, according to a genetic study by Plomin and Kovas (2005), the correlation between mathematics and reading abilities ranged from .47 to .76, and the correlation between disabilities in math and reading was .53. In another study, Silver et al (1999) investigated the stability of MD when assessed at 10 years of age and retested 19 months later, and greater stability in children with MD-RD was found than among children with MD-only.

To expand the knowledge about the mathematical word problem solving profiles of students with MD with and without RD, Fuchs and Fuchs (2002) used a hierarchy of three kinds of mathematical word problems: *arithmetic story problems* which presented essential, brief text contiguously with each question and which required one-step number facts for solution; *complex story problems* which presented longer but still relatively brief text including nonessential details (but no irrelevant numbers) contiguously with each question, and which required one-to three-step operations involving algorithms and applications; and *real-world problem solving* which presented extended text remote from the questions, including nonessential details and irrelevant numbers, and which required the same one-to three step math skills as those required for complex story problems. On each measurement, the accuracy of the students' performance decreased across the three problem-solving tasks. Averaged across the performance dimensions, the accuracy of students with MD-only fell from 75% for arithmetic story problems to 14% for complex story problems to 12% for real-world problem solving; among students with MD-RD, these percentages were 55%, 8%, and 5% respectively. Although this study failed to find reliable differences between complex story problems and real-world problem solving, the result has shown that the performance of students with MD-only was better than the performance of the other group, and that arithmetic story problems were comparable to either of the more difficult tasks (i.e., complex story problem or real-world problem solving).

Summary

Studies on the characteristics of students with MLD show substantial evidence that learner characteristics are significantly related to the mathematical word problem solving performance. In particular, cognitive skills such as procedural and fact retrieval skills, conceptual knowledge, and working memory are critical competencies required for successful mathematical word problem solving. Several studies also demonstrated that there is a need to separate groups of students who are MD-only and MD-RD because the performance of these two groups has shown different patterns across various research approaches. As Fuchs and Fuchs stated in their study (2002), if students with MD and MD-RD had not been grouped, the "differences evidenced between these two groups would simply have been cancelled out" (Rourke & Strang, 1978, p.65).

Procedures of Mathematical Word Problem Solving

Cognitive psychologists have investigated problem solving procedures for decades using mathematical word problems rather than other subject matter (Pressley & McComick, 1995). Several models to solve simple mathematical word problems based on cognitive theory, a cognitive model (e.g., conceptual phase model, Fuson, Hudson, & Pilar, 1997), a rule-based model (e.g., ACT; Anderson, 1983), and a schema-mediated model (e.g., Story Problem Solver; Marshall, 1995), have been proposed (Reed, 1999). In this section, types of mathematical word problems are discussed, followed by a description of the three models for word problem solving.

Types of Mathematical Word Problems

Based on the development of children's problem solving skills, Riley, Greeno, and Heller (1983) and Carpenter and Moser (1982) classified mathematical word problems into four categories, focusing on addition and subtraction problems only. The first category, c*hange*, is related to an exchange of quantity, and it causes increases or decreases in some quantity. Change problems consist of three subtypes: result unknown, change unknown, and start unknown. Each subset is different depending on the nature of the unknown. The second category is e*qualize* which involves two separate quantities, one of which is exchanged to become the same as the other quantity. In this category of problems, the solver must compare and equalize by either giving away or getting something. Third, *combine,* is the joining or separating of sets of numerical facts, and involves static relations between quantities. Combine problems require the problem solver to consider the difference between the quantities. Two subtypes of combine problems are: total set unknown and subset unknown. The fourth category, *compare,* also involves static relations between quantities, but the solver is asked to determine the difference between the quantities. Compare has three subtypes: difference unknown, compared quantity unknown, and referent unknown.

In contrast to Riley et al. (1983) and Carpenter and Moser (1982), Marshall (1995) categorized word problems into five situations, which include change, group, compare, restate, and vary problem types (see *Table 2.1*). These five situations describe sufficient relations within common mathematical story problems regardless of whether they are taken alone or in combination. In the current study, only multiplication and division problem types as identified by Marshall (1995) will be investigated. Therefore, restate problem (i.e., MC; multiplicative compare) and vary problem that require multiplication and division only will be investigated.

Table 2.1 Examples of the five situations

Change: Stan had 35 stamps in his stamp collection. His uncle sent him 8 more for a birthday present. How many stamps are now in his collection?
Group: In Mr. Harrison's third-grade class, there were 18 boys and 17 girls. How many children are in Mr. Harrison's class?
Compare: Bill walks a mile in 15 minutes. His brother Tom walks the same distance in 18 minutes. Which one is the faster walker?
Restate: At the pet store there are twice as many kittens as puppies in the store window. There are 8 kittens in the window. How many puppies are also in the window?
Vary: Mary bought a package of gum that had 5 sticks of gum in it. How many sticks would she have if she bought 3 packages of gum?

Note. Taken from Marshall (1995, p. 72)

Models of Word Problem Solving

One of the traditional models of mathematical word problem solving is the four-step model developed by Polya (1957). The four step model analyzed problem solving behavior and identified critical steps: (a) understanding the problem, (b) developing a plan, (c) carrying out the plan, and (d) looking back to check whether the solution makes sense. Although Polya's model provides a guide for teaching word problem solving and many teachers still use it (D'Augustine & Smith, 1992), its practical application to students with learning problems is limited. For example, Fleischner, Nuzum, and Marzola (1987) elaborated Polya's (1957) model and suggested more specific procedures such as:

(a) reading, (b) re-reading, (c) thinking, (d) solving, and (e) checking. However, given the fact that many students with learning problems have significantly below average levels of reading and little knowledge of problem solving strategies, teaching steps like “understanding the problem,” and “thinking” do not provide students with specific directions for generating the solutions.

A more comprehensive model was proposed later (Fuson et al., 1997). Fuson’s conceptual phase model for mathematical word problem solving includes four interrelated activities for each phase in solving the problem. First, the student reads the problem to understand the non-mathematical aspects of the context described in the problem (i.e., the *situation* conception). Second, the student attempts to understand the mathematical situation presented in the text while reading the problem and perhaps re-reading the problem, (i.e., the *mathematized* conception). These two processes are interrelated because the student cannot fully understand the mathematical situation until the semantics of the problem have been processed (Hegarty, Mayer, & Monk, 1995; Marshall, 1995; Nathan, Kintsch, & Young, 1992). Third, the student then needs to plan a solution method and generate the appropriate mathematical expressions (i.e., the *solution* conception). Finally, given the mathematical expression or expressions, the student computes the solution.

Models demonstrate that successful problem solving performance relies heavily on the content of students’ background knowledge in problem solving. Schoenfeld (1985) defined three types of background knowledge necessary for success in mathematical problem solving. The first type of knowledge is the knowledge of basic mathematical facts and computation skills. The second type is the knowledge of problem solving strategies. The third and most sophisticated type is metacognitive knowledge that enables a student to evaluate and monitor the entire process in the problem solving activity. While all types of knowledge are necessary for problem solving, research shows that knowledge of basic mathematical facts and computation skills and problem solving strategies are required for metacognitive knowledge to be used effectively (Montague, 1992; Montague et al., 1993). Unlike knowledge of basic facts and computation skills, knowledge of problem solving strategies covers an array of activities including knowledge of (a) critical problem solving steps, (b) various problem solving strategies, and (c) how and when to apply the strategies according to each problem situation (Reed, 1999).

Summary

Traditional models of mathematical word problem solving are valuable for understanding students' problem solving activities and providing students with procedural directions to follow. However, while the phases represent stages in solving mathematical problems, there are challenges for researchers and teachers: (a) filling in the details of the cognitive process that occur during each stage, and (b) developing the implications of this research for creating an effective curriculum (Reed 1999). In the next section, a schema-based instruction model and empirical intervention studies are discussed.

Schema Based Instruction

Schema theory has been often proposed by cognitive psychologists as one way to understand problem solving procedures. According to Marshall (1995),

> "A schema is a vehicle of memory, allowing organization of an individual's similar experiences in such a way that the individual; (a) can easily recognize additional experiences that are also similar, discriminating between these and ones that are dissimilar; (b) can access a generic framework that contains the essential elements of all of these similar experiences, including verbal and nonverbal components; (c) can draw inferences, make estimates, create goals, and develop plans using the framework; and (d) can utilize skills, procedures, or rules as needed when faced with a problem for which his particular framework is relevant (Marshall, 1995, p. 39)".

In other words, a schema is a chunk of information stored in long-term memory, specifying how a number of concepts are related to one another. People have schema for familiar events that determine how new information is interpreted and retrieved (Pressley & McCormick, 1995). Schema-based strategy allows students to approach the problem using the underlying semantic structure that gives meaning to each problem, and thus expand domain knowledge in which schemata are the central focus. Therefore the objective of the schema-based instruction is to encourage learners to become active problem solvers, rather than to produce students who only possess a large amount of passive or static knowledge (Marshall, 1995). In the current study, a model for schema-based strategy instruction is described based on the work of Marshall (1995) and Riley et al.'s work (1983) which comprises four problem solving procedural stages: identification, elaboration (i.e. representation), planning, and execution (i.e., solution carrying-out) (Marshall, 1995).

Identification Knowledge

The first stage of the problem solving process is identification knowledge. The central function of identification knowledge is pattern recognition. Because pattern recognition occurs in many concurrent features of cognitive processing, not only with a single feature, the components of identification knowledge and their associations are not easily found. Although problems may have different configurations, they must all be recognized as the same basic situation if certain specific characteristics are noticed. For example, Marshall (1995) described the requirements for a multiplicative compare situation and a vary situation: (a) a multiplicative compare situation is present if the value of one object is described as a scalar function of the value of another object, and (b) a vary situation exists when a specified relationship connecting two things can be generalized over other manifestations of those things. The two things may be two different objects or one object having a measurable property associated with it.

Elaboration Knowledge

The second stage involves elaboration knowledge which enables an individual to create a mental model of the current problem. Once the identification knowledge has succeeded in recognizing the general situation or experience, the details of the current experience will fit into a pattern. This is an interpretive step in using schema knowledge. This interpretation is made possible based on sufficient details and general descriptors in the schema's elaboration knowledge. The frameworks constituted by both identification and elaboration knowledge allow the individual to form a tentative hypothesis about a situation and then to test it (Marshall, 1995).

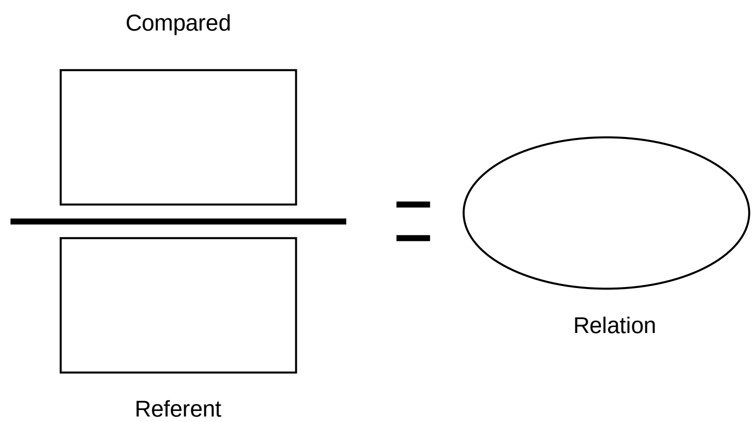


Figure 2.1. Schematized representation of the multiplicative compare problem type. Taken from Jitendra (2007, p. 173)

To elaborate the multiplicative compare problem situation, there are five basic parts including the compared set that includes the identity of this set and numerical values, the referent set that includes this set's identity and numerical values, and the relationship that indicates a scalar function linking the above two sets (see *Figure 2. 1*). The important part of the elaboration knowledge in the multiplicative compare schema is the semantic relationship or the scalar function between the two sets. For the vary problem type, three elements could be perceived including the main dimension (or main object), a second dimension (or a second object) that is associated with the main dimension, and the nature of that association. With these three elements, two pairs of associations form the vary problem situation. The first pair declares the main dimension or object, a second dimension or object, and the association relating the two (e.g., 1 to 2); the second pair declares the variation of the value or quantity of one dimension, and tasks for the corresponding change in the value of the other dimension (see *Figure 2.2*). Elaboration of this two pair association in the vary problem therefore reveals four slots into which the numerical values are placed.

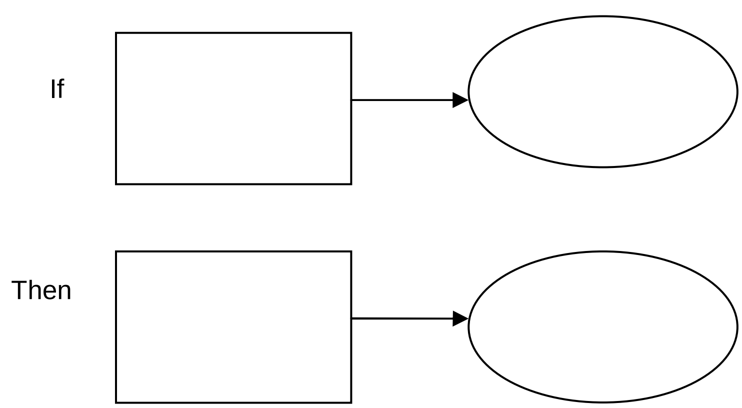


Figure 2.2. Schematized representation of the vary problem type. Taken from Jitendra (2007, p. 220)

The third stage is planning knowledge which refers to the way in which the schema can be used to make plans, create expectations, and set up goals and subgoals. Use of the schema will not necessarily be straightforward. This knowledge is acquired from experience in using each schema and is updated steadily with such use. Planning knowledge is considered important because it helps researchers to determine whether or not an individual has a schema. It is quite plausible that an individual could recognize a situation using identification and elaboration knowledge but have no planning knowledge. Such an individual would not be considered to have a working schema. The working schema involved in planning is directly related to a basic conceptual understanding that is critical in helping the problem solver decide which operation to use. The positioning of the known and unknown quantity in the schematic diagram help decide the choice of operation.

Execution Knowledge

The last stage of problem solving is execution knowledge which allows the individual to carry out the steps of the plans and execute the arithmetic operation of multiplying or dividing. Many schemas will share the same execution knowledge generously, which consists of techniques that lead to action, such as performing operations or following an algorithm. For example, the execution knowledge associated with the vary problems is also related to conceptual knowledge of ratios and proportions (Marshall, 1995).

Schema-based Intervention Studies for Students with Mathematics Difficulties

Several research studies that have investigated math problem solving instruction for students with LD and those at risk for mathematics failure have emerged in the last few decades. The synthesis by Xin and Jitendra (1999) reviewed twenty five published and unpublished research studies (i.e., 14 group design studies and 12 single subject design studies, with one study involving both group and single subject design, Hutchinson, 1993, [study 1 & 2]) across student characteristics (e.g., grade, IQ), instructional features (e.g., intervention approach, treatment length), methodological features, maintenance, and generalization components. The effectiveness of word-problem solving interventions for students with LD was examined using effect sizes. Strategies investigated in the obtained published and unpublished studies included representation techniques, strategy training (i.e., schema-based intervention, and cognitive/metacognitive intervention), computer aided instruction (CAI), and other strategies (e.g., key word instruction, task variation instruction).

Results of the review (Xin & Jitendra, 1999) indicated that the CAI showed the largest effect size for group design studies, followed by strategy training instruction in group design studies. A schema-based intervention and cognitve/metacognitive intervention, both of which used strategy training, were most effective for students' word problem solving performance in the single subject design studies. However, the CAI approach was used in only the group design studies and the effective instructional strategies were employed with a form of tutorial programs or videodisc instruction, this category should be considered as strategy training (e.g., cognitive/metacognitive strategy, or schema-based strategy). Therefore, consistent with the results of a previous literature review (Jitendra, & Xin, 1997), those interventions emphasizing semantic structure understanding or schema knowledge mediated diagramming were found to be more effective than other strategies in facilitating students' mathematical word problem performance.

The importance of teaching the semantic structure representation of problems to improving students' word problem solving performance has been emphasized in the literature. For example, Zawaiza and Gerber (1993) compared the effects of two types of problem solving strategies (i.e., translation and diagram strategies) to examine the effects of explicit instruction on the comprehension of the semantic structure of arithmetic problems (i.e., *compare*) by community college students with LD. Thirty eight college students with LD were randomly assigned one of three groups of transition strategy, diagram strategy, and attention-control group. The translation group was taught to identify componential statements in problems wherein the value of one variable was defined in terms of another by illustrating the three types of statements (i.e., assignments, relations, and questions). The main objective of this condition was to identify the componential statements (i.e., assignments, relations, and questions) in the compare problems. Students in the diagram strategy group were taught this same translation strategy, and were also taught schema strategies for diagramming relationships between word problem components and developing an action schema. The attention-control group received no instruction, but was exposed to similar types of problems as the other two groups and they discussed the problems and their own strategies. The training sessions provided to the translation and diagram strategy groups consisted of direct instruction in the strategy, modeling of behavior, guided and independent practice of behavior, and corrective feedback.

Results showed that all groups improved their performance from pre to post training measures, but no statistically significant differences were found among the three groups. In particular, students in the diagram group made significantly fewer reversal errors, while students in the translation groups showed an increase in reversal errors from the pretest to posttest. Across the three groups, students made statistically more representation errors than calculation errors and committed more errors on the problems with inconsistent language than on those with consistent language (i.e. keyword cuing on operation). Consistent with the Lewis (1989) study, the results of this study demonstrated that postsecondary students with LD were responsive to semantic structure representation strategy instruction in that it helped them to improve their problem solving performance.

An additional study by Hutchinson (1993) also illustrates the use of semantic representation strategy training. Specifically, Hutchinson (1993) studied the effects of instruction in the use of diagrammatic representations of mathematical relational structure combined with teaching cognitive strategies on the word problem solving performance of twenty students with LD in grades 8-10 for three types of algebraic word problems (i.e., relational, proportion, and two-variable two-equation). Intervention strategies such as modeling, thinking aloud, prompting, corrective feedback and self-questioning techniques were used to teach students to represent and solve word problems. Think-aloud data gathered prior to instruction in representation and solution showed low means on representation (i.e., 4.2 out of 12) and solution (i.e., 2.8 out of 8). The goals and information given in the problem were the aspects of representation most frequently verbalized by students. Choice of operation and execution of operation were the aspects of solution verbalized by students when parts of the solution were verbalized. In addition, students drew segments of line to represent the value of different variables and the semantic relations expressed in the problem. The solution strategy teaching was related to using algebra equation manipulation to determine the answer for the unknown variable. After instruction, the mean for post test relational problems was 10.6 out of 12 for representation and 7.1 out of 8 for solution. The results of this study indicated that representation training that emphasizes conceptual understanding of mathematical relations with teacher modeling, think-aloud procedures, and self-questioning metacognitive strategies, was effective in increasing the performance of adolescent students with LD in solving algebra word problems.

More recently, a series of research studies indicated that the use of schema-based diagrammatic procedures and strategic instruction improve students' word problem solving skills. Jitendra and her colleagues examined schema-based intervention on the mathematical word problem solving performance of students with LD, and those at risk for mathematics failure (e.g., Jitendra et al., 1998; Jitendra & Hoff, 1996; Jitendra et al., 1999; Jitendra et al., 2002; Xin et al., 2005).

For example, Jitendra and Hoff (1996) examined the effects of schema-based strategic instruction on the word problem solving performance of students with LD. The participants were one male and two females from ages 8 to 10 in a general education inclusive setting. The training involved two sessions: problem schema instruction and intervention. Specifically, during problem schema instruction, three types of problem schema (i.e., change, combine, compare) were introduced. Next, students were taught to map text components or situation features onto the schemata diagram of each problem type. The schemata instruction was followed by the intervention session. The only difference between problem schemata instruction and the intervention session was that during schemata instruction whereas the intervention session included problems with an unknown story situations not involving unknown were presented. Intervention lasted forty to forty five minutes for five to ten days. The participants' overall mean score increased from 25% to 95.9% after strategy training was combined with problem schemata. The training scores for follow-up were 75.3% and 82.0%. No generalization or transfer data were reported. The result of this study demonstrated the effectiveness of an explicit schema knowledge mediated instruction that teaches conceptual understanding and efficient execution of problem solving procedures.

In another study, Jitendra et al., (1998) studied the differential effects of explicit schema-based strategy instruction and traditional strategy instruction on the acquisition, follow-up, and generalization of word problem solving skills (one step addition and subtraction). Thirty four elementary students with mild disabilities or at risk for math failure participated in the study. Intervention occurred for forty to forty five minutes in groups of five to six students for seventeen to twenty days. Schema training involved two discrete steps in change, group, and compare word problems. First, students identified the features of the semantic relations (i.e., problem schema) in the problem and checked for the presence of elements of the chosen problem schema (i.e., change, group, or compare), then mapped the features into schema diagrams. Second, participants were taught a solution strategy (i.e., action schema) and how to choose and implement the correct operation. The comparison group did “Think Math” activities including logical reasoning, discovering patterns, number puzzles, number relationships, money, and place-value.

Results indicated that both groups’ performance improved from the pretest to posttest, and both groups showed maintenance and generalization of the use of their problem solving skills. However, the schema instruction group outperformed the comparison group on the posttest, delayed posttest, and on a generalization test. In addition, the performance of the schema instruction group on the posttest and delayed posttest (i.e., 77% and 81% correct respectively) were comparable to that of a sample of normal achieving students (i.e., 82% correct).

More recently, Xin et al. (2005) also investigated the effects of schema-based instruction on the multiplication and division word problem solving performance of middle school students with learning problems. Eighteen students with LD, one student with severe emotional disorders, and three at-risk students in mathematics in grade 6-8 participated in the study. Specifically, those students were randomly assigned to either the schema-based instruction or general strategy instruction group. The students received one-hour of instruction about solving multiplicative compare and proportion problems three to four times a week. The students in the schema based instruction group received 4 sessions for multiplication compare and vary problems respectively and 4 sessions for mixed word problems that included both types. The components and procedures of schema-based instruction were similar to those used by Jitendra et al. (2002), and they included a schemata instruction phase and solution instruction phase. During the schemata instruction phase, the students learned to: (a) identify the problem's key features, type and structure; (b) map the information onto a diagram; and (c) summarize the information in the problem using the complete diagram. During the problem solution instruction phase, students learned to; (d) transform the information in the diagram into a math sentence and solve it; and (e) write and check a complete answer. The students in the general strategy instruction group had twelve one-hour sessions for mixed word problems and were not given instruction in identifying and elaborating the two word problem types (i.e., multiplicative compare and vary problems). Instead, they received more typical strategy instruction which followed a four step problem solving procedure found in many commercial mathematics textbooks. Specifically, the students learned to: (a) read; (b) develop a plan; (c) solve; (d) and look back. Four parallel word problem solving test including 16 one-step multiplicative compare and vary word problems were used for the pre, post, maintenance, and follow-up tests.

Results showed that the students who were provided with schema based intervention performed significantly better than those in the general strategy instruction group on the posttest, maintenance test, and generalization test. However, this study had limitations in that pretest performance within each group on both target and transfer problems showed great variation, it failed to control the students' reading level, and they used standard text-based word problems rather than real-world problems.

Summary

Schema-based instruction has its roots in cognitive theory related to problem solving and the goal is to teach domain knowledge in which schemata are the central focus. Schema-based instruction explicitly analyzes the links pertaining to how and why different elements of the schema or the domain are related (Marshall, 1995). These links are essential in finding the patterns of association and relations that are critical in making appropriate choices of operations during the process of mathematical word problem solving (Marshall, 1995). Schema-based instruction allows students to approach the problem using the underlying semantic structure that gives meaning to each problem, and thus improves word problem solving skills.

Summary

In summary, the effectiveness of schema-based instruction in improving students' mathematical word problem solving performance is clear. However, studies that have employed schema-based intervention have generally failed to control students' reading levels and have suggested that it would be useful to investigate the effects of using these instructional strategies while controlling for students' reading skills (i.e., Jitendra et al., 2002; Xin et al., 2005). Given the research about the relationship between reading skills and mathematics disabilities, it is clear that reading comprehension is an important contributing factor to students' word problem solving performance (Zentall & Ferkis, 1993). Therefore, this study focused on a more homogeneous groups of students (i.e., LD in mathematics) in order to examine the effectiveness of schema-based intervention on the ability of students to solve multiplication and division word problems. The use of standard text-based word problems was reported as another limitation of previous studies focused on multiplicative compare and division problems (i.e., Xin et al., 2005). Instead, real-world problem solving tasks developed by using the Mathematics Student Interest Inventory (Allsopp et al., 2008) were used to assess the transfer of learned skills in this study. The social validity of the intervention was evaluated by examining students' satisfaction with the schema-based intervention (Jitendra et al., 1999).

CHAPTER 3

METHODS

Word problems in mathematics are challenging for many students because of the complexity of the problem solving process (Jonassen, 2003; Miller & Mercer, 1993; Schurter, 2002). Furthermore, students with LD have significantly more difficulty in solving math word-problems than their peers without LD (Cawley & Miller, 1989; Montague & Applegate, 1993). Researchers have indicated that solving an array of seemingly different, but structurally similar problems will promote the development of generalized problem solving skills and schema knowledge that are the primary components of skilled problem solving performance (Chen, 1999; Didierjean & Cauzinille-Marmeche, 1998; Fuson & Willis, 1989; Mayer & Hagarty, 1996; Sweller et al., 1990). According to the findings of a meta-analysis study (Xin & Jitendra, 1999), schema-based instruction that emphasizes semantic and problem structure understanding using schematic diagramming is more effective than other strategies such as key word instruction, sequential instruction only, or metacognitive instruction only. Schema-based instruction allows students to approach the problem by focusing on the underlying semantic or problem structure, thus facilitating conceptual understanding and adequate skills (Marshall, 1995). However, students with LD are not typically provided this type of learning experience with traditional mathematics problem solving instruction (Parmar et al., 1996). Thus, the purpose of this study was to examine the effectiveness of schema-based instruction on the mathematical word problem-solving skills of middle school students with LD.

Four research questions guided this study: (a) To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after schema-based intervention?; (b) To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed by using the Mathematics Student Interest Inventory (Allsopp et al., 2008)?; (c) To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy to solve multiplication and division word problems?; (d) How do students with LD in grades 6-7 evaluate the effectiveness and acceptability of the schema-based instruction? This chapter describes the methodology proposed for this study including: (a) research design, (b) participants, (c) setting, (d) instructional materials, (e) measures, (f) procedures, and (g) data analysis.

Research Design

A nonconcurrent multiple baseline (MB) design was used to measure the effects of schema-based strategy intervention on the one-step multiplication and division word problem solving skills of four students with learning disabilities. The nonconcurrent MB design, first proposed by Watson and Workman (1981), incorporates the features of a traditional concurrent MB design; however, measurements and manipulations across data series are not temporally aligned. Although both the concurrent and nonconcurrent MB designs require the a priori specification of experimental manipulations across data series (Christ, 2007), the degree of specification is greater when nonconcurrent designs are used, whereas the order for phase changes must be specified when data are collected concurrently. The actual duration of baseline phases must be specified and assigned to participants prior to data collection when data are collected nonconcurrently (Watson & Workman, 1981). Experimental control of the nonconcurrent MB design is demonstrated by the establishment of a priori baseline durations with specification of conditions combined with the random assignment of participants (Christ, 2007). Watson and Workman (1981) demonstrate that the nonconcurrent MB design is “sufficiently robust to contribute meaningfully to the scientific literature” as an experimental design.

In this study, four middle school students with learning disabilities participated in the pre-experimental (i.e., introduction, screening test, and Mathematics Interest Inventory session) and experimental (i.e., baseline, intervention, post-intervention test with generalization test, and maintenance test) session over a 13-week period. Participants were randomly assigned to a priori baseline durations (e.g., 6, 9, 12, 17 days) for each intended data series.

Participants

To find participants for the study, the researcher contacted a drop out prevention specialist who had successfully run a one-to-one tutoring program in the targeted middle school. The researcher met with the specialist and the school principal, informed them about the study, and asked whether they were interested in their students participating in the study. After getting a letter giving permission to conduct the study in the school, the researcher contacted the research office of the school district located in Texas, and submitted a research proposal and consent forms for approval. Following school and district approval, the researcher submitted an Institutional Review Board (IRB) proposal to the university. After the final university approval of both the school district and the university's IRB, the drop out prevention specialist and the special education teachers were asked to identify the students who might meet the participant selection criteria for the study. The researcher provided the drop out prevention specialist with written consent forms in both English and Spanish for parents or guardians to sign. The students' IEPs were collected from their special education teachers. District and school demographic information was also obtained. The detailed demographic information of the district and school was collected (see Table 3.1).

Table 3.1.
District and School Demographic Information

Demographic	District	School
Total Enrollment	83,483 (100%)	947 (100%)
African American	9,792 (11.7%)	93 (9.8%)
Asian	2,869 (3.4%)	33 (3.5%)
Hispanic	49,143 (58.9%)	685 (72.3%)
Native American	199 (0.2%)	4 (0.4%)
White	21,489 (25.7%)	132 (13.9%)
Economically Disadvantaged	62.5%	69%

Source: Texas Education Agency, 2008-2009

Six students in grades 6-7 were nominated by the drop out prevention specialist in the school as possible study participants. Four students in grade 7 had been identified as having learning disabilities in mathematics. However, the researcher did not obtain consent from the guardians of one of the seventh grade students. As a result, only the remaining five students including two six graders were eligible for the study based on their teachers' rating on their mathematical competence in the resource class. All of the five students had below grade level mathematics scores on the Texas Assessment of Knowledge and Skills (TAKS) conducted in spring 2008. Specifically, the criteria for participation in this study were as follows: (a) students had been diagnosed with learning disabilities according to the state standards and district eligibility criteria; (b) students had targeted mathematics goals on their Individualized Education Program (IEP); (c) students had been placed in the resource mathematics course by the Admission, Review, and Dismissal (ARD) committee because of significant learning problems in the area of mathematics primarily due to learning disabilities; (d) students had scores that were below the score that is required to pass (i.e., below 2100) in mathematics on the TAKS in spring 2008; (e) students' reading scores given by the language art teacher were over 70 on the test administered in their class. Because mathematical word problems are related to reading comprehension and reading fluency (Fuchs, Fuchs, & Prentice, 2004; Vilenius-Tuohimaa, Aunola, & Nurmi, 2008), students' reading skills needed to be controlled in the study; and (f) once the five students returned the signed parental consent and student assent forms, they took a screening tests to ensure their eligibility for the study. The students had to score at 50% or lower on the screening test. The criterion level of mastery (i.e., less than 50%) on the screening test was suggested in previous research employing schema-based intervention (Jitendra et al., 2002). Among the five students who met all the criteria, one student had a schedule conflict after the study started. Finally, four out of the five students were able to participate in the study. More detailed information about each student is given below, based on information provided to the researcher by the district's research office: After receiving the signed consent forms from each student's parents or guardians, the researcher asked the research office of the school district for student demographic information (e.g., grade, gender, ethnicity, eligibility for free or reduced price lunch, TAKS scores in math and reading, and grades given by teachers in math and reading). Table 3.2 presents detailed demographic information for the four participating students (i.e., age, grade, gender, spring 2008 TAKS scores in reading and math, and screening test score).

Table 3.2
Participant Demographics and Testing Information

Variables		Student 1	Student 2	Student 3	Student 4
Age		13 years old	13 years old	12 year old	12 years old
Gender		Female	Male	Male	Male
Grade		7th grade	7th grade	6th grade	6th grade
Ethnicity		Hispanic	Hispanic	African American	African American
Disability Label		Learning Disabilities	Learning Disabilities	Other Health Impairment, Learning Disabilities	Learning Disabilities
Difficulty Area		Math & Reading	Math & Reading	Math & Reading	Math & Reading
SES (eligibility for free/reduced lunch)		Non-eligible	Free/reduced lunch	Free/reduced lunch	Free/reduced lunch
TAKS Scores	Reading	1635	1859	1913	n/a*
	Math	1844	1739	1724	n/a*
Screening test percentage score		10%	0%	10%	0%

Note. SES = Socioeconomic Status. TAKS = Texas Assessment of Knowledge and Skills/ Score of 2100 is required to pass in both reading and math. N/A = Not Applicable. * = Student who took TAKS-M (TAKS Modified) does not have a score because the score does not count towards a school's academic progress.

Student 1 was a 13-year-old Hispanic female in the 7th grade. Her TAKS score was 1844 points in mathematics, which is lower than the score of 2100 required to pass. Her mathematics score (i.e., 75 points) on the report card in her resource class was above the acceptable passing score (i.e., 70 points) for the school; however, her teacher had reported that she needed extra help in mathematics. She had received intensive mathematics instruction from special education teachers in mathematics and usually attended reading tutoring for 50-55 minutes once a week. Based on her classroom teacher's rating, Student 1 had below average reading and math skills; however, she could read well enough to understand paragraphs with simple sentences. She rarely exhibited behavioral problems in the classroom.

Student 2 was a 13-year-old Hispanic male in the 7th grade. His TAKS score of 1739 points in mathematics was lower than the passing score. His mathematics score (i.e., 78 points) on the report card in his resource class was above the acceptable passing score (i.e., 70 points) for the school; however, he was also reported to need extra help in mathematics by his teacher. Like Student 1, he had received intensive mathematics instruction from special education teachers in both mathematics and reading; however, he had not received individual tutoring. Based on his special education teacher's rating, Student 2 had a below average level in reading and math skills; however, he could read well enough to understand paragraphs with simple sentences in terms of reading similar to Student 1. His teacher also had rarely reported him having behavioral problems in the classroom.

Student 3 was a 12-year-old African American male in the 6th grade. He had scored 1724 points on the TAKS test in mathematics, which was lower than the required to pass. His mathematics score (i.e., 88 points) on the report card in his resource class was above the acceptable passing score (i.e., 70 points) for the school; however, his teacher reported that he needed extra help in mathematics. Like both Students 1 and 2, he had received intensive mathematics instruction from special education teachers in terms of mathematics and reading and he had also received individual tutoring in reading once a week for 50-55 minutes from a famous football player. Based on his classroom teacher's rating, Student 3 although he had a below average level in reading and math skills, he could read paragraphs with simple sentences and understand the content. His teacher had reported frequent behavioral problems in the classroom.

Student 4 was a 12-year-old African American male in the 6th grade. His TAKS score in mathematics was not available because he took the TAKS-Modified version which does not have a score because the scores do not count towards a school's academic progress. His mathematics score (i.e., 60 points) on the report card in his resource class was below the acceptable passing score (i.e., 70 points) for the school. He was also reported to need extra help in mathematics by his teacher. He had received intensive mathematics instruction from special education teachers for mathematics and reading, and individual tutoring in reading and math were provided once a week for 50-55 minutes. Based on his classroom teacher's rating, Student 4's reading and math skills were below average, but he could read well enough to understand paragraphs with simple sentences. He was rarely reported as having behavioral problems, but seemed to have certain social problems.

Setting

The study was conducted in the same area in the school where a tutoring program that is part of a drop out prevention program is held. This tutoring area was equipped with several tables and chairs for the daily tutoring and most of time, two to three individual tutoring groups were working in the area. The tutoring area was spacious and quiet. Students participated in the study interventions during regularly scheduled resource classes.

Instructional Materials

The instructional materials and types of word problems used in this study were adapted from two programs of schema-based instruction developed by Jitendra and her colleagues (Jitendra, 2007). The materials included scripted lessons for each instructional phase, student note sheets, checklists, and diagrams. Instructional steps for Multiplicative Compare and Vary problem solving are summarized in *Tables 3.3* and *3.4*.

Multiplcative Compare Problems

Problem schemata instruction. When teaching the multiplicative compare problem schema, students learned that a multiplicative compare problem includes (a) a referent set, including its identity and its corresponding quantity; (b) a compared set, including its identity and corresponding quantity; and (c) a statement that relates the compared set to the referent set (Marshall, 1995). Students were first taught to identify the problem type using story situations without unknown information. Students were provided with a prompt sheet containing the key features of the problem type and the two strategy steps (i.e., Find the problem type; Organize the information in the problem using the MC problem diagram, (FO)). Step 1 involves identifying and underlining the relational statement in the problem. In Step 2, students were required to identify the referent, the compared, and the relation, and correspond the information onto the multiplicative compare diagram. They were encouraged to check the completed diagram by reviewing the information related to each component (i.e., the referent, compared, and relation) of the multiplicative compare problem.

Problem solution instruction. During the problem solving instructional phase, students learned to solve for the unknown quantity in word problems with a checklist containing four strategy steps (i.e., Find the problem type, Organize the information in the problem using the MC problem diagram, Plan to solve the problem, and Solve the problem, (FOPS)). Instruction focused on representing the problem using the diagram, as in the problem schema instruction phase. Additionally, during the problem solution instruction phase, students were taught to use a question mark to flag the unknown quantity in the diagram. In Step 3, students learned to translate the information in the diagram into a math sentence and solve for the unknown. In Step 4, students were required to write a complete answer and check the rationality of their answer. Checking the accuracy of both the representation and the computation was emphasized. *Figure 3.1* shows an example of MC problem solving with the MC diagram.

Table 3.3. Multiplicative Compare (MC) Problem Solving Steps (FOPS)

Instructional Step	Problem Schemata	Problem Solution	Action
Step 1	Find the problem type	Find the problem type	Read and retell the problem Ask if it is an MC problem Look for the MC words, such as "n times as many," "as much as," or "n^{th} of," to see whether there is a comparison sentence that tells about a multiple (e.g., 2 times) or partial (e.g., 2/3) relation?
Step 2	Organize the information in the problem using the MC problem diagram	Organize the information in the problem using the MC problem diagram	Underline the comparison sentence, circle the two things compared (i.e., compared and referent), and write them in the diagram Write the relation between the compared and the referent in the diagram Underline the compared and referent, circle numbers and labels for the compared and referent, and write them in the diagram Write a "?" for what must be solved (only in Problem Solution)
Step 3	n/a	Plan to solve the problem	Translate the information in the diagram into a math equation
Step 4	n/a	Solve the problem	Solve the math equation Write the complete answer Check whether the answer makes sense

MC problem: Ray has 4 crayons. Crystal has 5 times as many crayons as Ray. How many crayons does Crystal have?

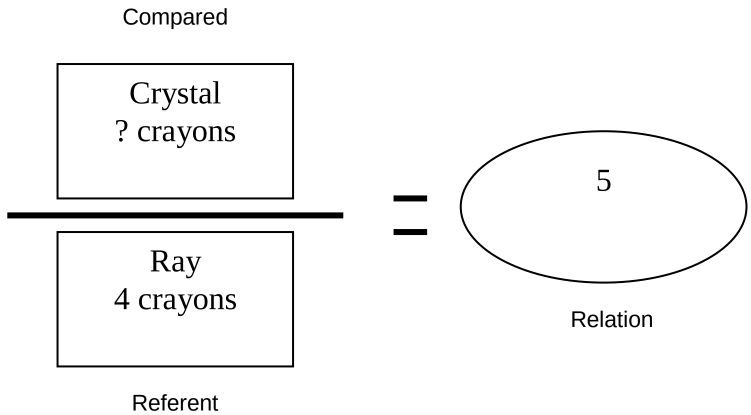


Figure 3.1. Multiplicative Compare problem solving with a MC diagram. Taken from Jitendra (2007, Reference Guide: MC lesson 2)

Vary Problems

Problem schemata instruction. When teaching the vary problem schema, students learned that (a) the proportion problem describes an association (i.e., a ratio) between two things; (b) there are two pairs of associations between two things that involve four quantities; and (c) the numerical association (i.e., the ratio) between two things is constant across two pairs (Marshall, 1995). Students first learned to identify the problem type using the sample story with an "if-then" statement that makes up two pairs of associations. A prompt sheet containing the key features of the problem type and the two strategy steps (i.e., Find the problem type; and Organize the information in the problem using the vary diagram, (FO)) was given to the students. Step 1 involved identifying the two pairs of associations that form a rate or ratio in the story situation and defining one as the subject and the other as the object. In Step 2, students identified the two pairs of numerical associations and mapped the information onto the vary diagram. Correct alignment of the subject and object with their corresponding quantities was emphasized.

Table 3.4. Vary Problem Solving Steps (FOPS)

Instructional Step	Problem Schemata	Problem Solution	Action
Step 1	Find the problem type	Find the problem type	Read and retell the story Ask if it is a vary story Look for a rate or ratio type of association between two things See if the story involves an “if-then” statement that makes up two pairs of associations
Step 2	Organize the information in the problem using the vary problem diagram	Organize the information in the problem using the vary problem diagram	Underline the two things that form a specific rate or ratio and write their names in the diagram Circle numbers for each of the two pairs of associations and write numbers and labels in the diagram Write a “?” for what must be solved. Find the question sentence (only in Problem Solution)
Step 3	n/a	Plan to solve the problem	Translate the information in the diagram into a math equation
Step 4	n/a	Solve the problem	Solve the math equation Write the complete answer Check if the answer makes sense

Problem solution instruction. In the problem solving instructional phase, problems with unknown information were presented with a checklist containing four strategy steps (i.e., Find the problem type, Organize the information in the problem using the vary diagram, Plan to solve the problem, and Solve the problem (FOPS)). Instruction focused on representing the problem using the diagram, as in the problem schema instruction phase. Different from the problem schema instructional phase, during the problem solution instruction phase, students additionally were taught to use a question mark to flag the unknown quantity in the vary diagram. In Step 3, students learned that the math equation can be derived directly from the diagram because the proportion problem schema entails a constant ratio across two pairs of associations. They were taught how to use cross multiplication to solve for the missing value in the equation. Next in Step 4, students were required to write a complete answer and check the rationality of their answer. Checking the accuracy of both the representation and the computation was emphasized. *Figure 3.2* shows an example of vary problem solving using the vary diagram.

Vary problem: Ms. Baker made 60 almond cookies using 8 eggs. If Ms. Baker has only 2 eggs, how many almond cookies can she make?

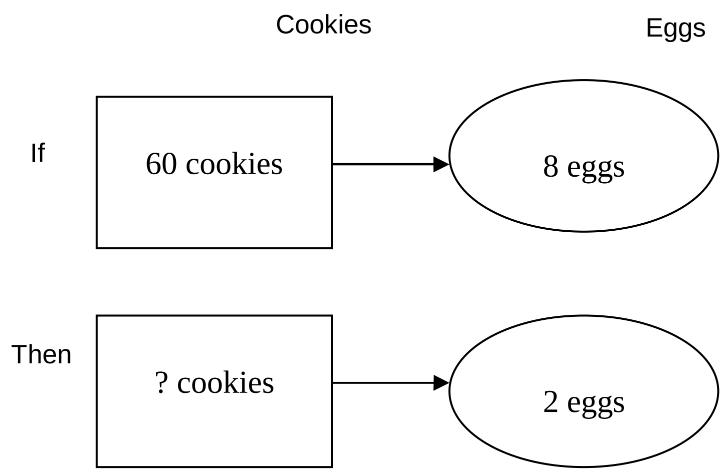


Figure 3.2. Vary problem solving with a vary diagram. Taken from Jitendra (2007, Reference Guide: Vary lesson 7)

Measures

Word Problem Solving Performance

The dependent variables in this study were the one-step multiplication and division word problem solving performance of four students with LD and the students' satisfaction with the strategy intervention. Five forms were developed for use as the screening, baseline, intervention, maintenance, and generalization tests. Each test contained ten target problems of *multiplicative compare* and *vary* problems that were similar to the problems used during the intervention. Specifically, six multiplicative comparison problems and four vary problems were included in each test. The six *multiplicative compare* problems consisted of two problems with the *compared unknown*, two problems with the *referent unknown*, and two problems with the *scalar function unknown*; the four *vary p*roblems consisted of two problems with the *unit value unknown*, and two problems with the quantity of *either one of the two dimensions unknown*. The two types of word problems were presented in random order on all four tests. Each test was comprised of ten problems derived from commercially published mathematics textbooks (e.g., Charles, Barnett, Briars, et al., 1999; Charles, Dossey, Leinwand, et al., 1999; Clements, Jones, Moseley, & Schulman, 1999), a progress monitoring test (i.e., Fuchs, Hamlett, & Fuchs, 1999), and Jitendra (2007)'s manual. In addition, all the test sheets provided students with enough space for them to show their work while solving each problem.

The students' performance on multiplication and division word problem solving was assessed based on the number of problems that were solved correctly. Items on the word problem tests were scored as correct and awarded 1 point if the correct answer was given. The researcher scored all tests using an answer key. A second rater rescored 30% of the tests. Interrater reliability was computed by dividing the number of agreements and disagreements and multiplying by 100. Mean scoring reliability was 100% for all tests across the two independent raters.

Treatment Fidelity and Inter-observer Agreement

For each instructional condition, a checklist that contained critical instructional steps was developed to assess the instructor's adherence to the assigned strategy instruction. Fidelity of implementation was assessed for about 23% of the intervention sessions by a doctoral student in special education. For interobserver agreement, 20 % of the sessions assessed for the fidelity of implementation were assessed by two graduate students. Both the fidelity and the interobserver agreement was 100%.

Strategy Satisfaction Questionnaire

The strategy satisfaction questionnaire was modified by the researcher from the one developed and used by Jitendra, Hoff, and Beck (1999). In the first part of the modified questionnaire, a Likert-type scale of 1 (strongly disagree) to 5 (strongly agree) was used for the students to provide information about whether (a) they enjoyed the intervention, (b) the strategy was helpful in solving word problems, (c) their word problem solving skills were improved, (d) they would recommend using the strategy with their peers, and (e) they would continue to use it to solve word problems in the classroom (Jitendra, Griffin, Deatline-Buchman, & Sczesniak, 2007). A question about their overall satisfaction with the strategy instruction was additionally included in this section. An open question about what they liked or suggestions for the intervention was asked in the second part of the questionnaire. The student satisfaction questionnaire was reviewed by a mathematics teacher and a professor in special education for appropriateness.

Procedure

Screening test

Prior to the study, a screening test that contained ten word problems was provided to the potential participants who met the selection criteria. During the test, each student was presented with a worksheet and instructed to work the problems independently. No further instruction was given, but students were allowed to use calculators. Students scoring 50% or lower on the word problem solving test involving multiplication and division word problems met criteria for being included in this study (Jitendra et al., 2002).

Student Interest Inventory

Based on the knowledge that students benefit from instruction and assessment that occurs within an authentic context (e.g., Bottage, 1999; Bottage, Heinrichs, Chan, Mehta, & Watson, 2003; Bottage, Heinrichs, Mehta, & Hung, 2002; Gersten, 1998; Schumm, Vaughn, Haager, Mc-Dowell, Rothlein, & Saumell, 1995; Wehmeyer, Palmer, & Agran, 1998), the researcher evaluated the participants' interests for the purpose of developing authentic contexts for the generalization tests using the Mathematics Students Interest Inventory (Allsopp et al., 2008). The students described their interests and experiences, including their individual interests, peer related interests, and family related interests. After evaluating the four students' responses to the interest inventory, the researcher integrated this information into word problems to be used on the generalization tests.

Experimental Period

Baseline probe. Baseline testing for each participant was conducted using a word problem test that had a total of ten problems, including both multiplicative compare and vary problems given calculator. The first baseline probe was conducted the day following the screening test. Participants were given as much time as needed. No instruction was given in this phase, but feedback was given when the students asked. Each student had six sessions during his or her a priori determined baseline duration (i.e., 6 days, 9 days, 12 days, and 17 days).

Intervention. Intervention instruction occurred in two phases; problem schemata instruction and problem solution instruction for both the multiplicative compare and vary problems. During problem schemata instruction, students learned the representation of the underlying structure of a specific problem type. In this phase, students were provided instruction on how to identify the problem type or structure and represent the problem using a schematic diagram and story problems without unknown information. For the problem solution instruction phase, story problems with unknown information were used.

All instructional procedures were implemented using scripted lessons modified from the version developed by Jitendra and her colleagues (Jitendra, 2007). Each instructional session lasted 30-40 minutes. Schema-based strategy problems were presented in two phases: problem identification, and problem solution. Participants received twelve sessions of intervention with six sessions of problem schemata identification and six sessions of problem solution intervention, respectively because twelve sessions have been noted in the literature as a reasonable amount of time for acquiring word problem solving skills (Jitendra et al., 2002). Overall, intervention occurred three to four times a week, with each session lasting about 30-40 minutes. The same procedures were applied to all the participants.

Post-intervention phase. After the intervention phase, students completed three achievement and three generalization tests, each consisting of six *multiplicative compare* and four *vary* problems. The test administration procedures and conditions for the generalization tests were identical to those of the baseline tests. The criterion performance level was 70%. No instruction was given during this phase.

Maintenance test. To determine the maintenance of the intervention, each of the students took two achievement tests and two generalization tests two weeks after the intervention phase. These tests also contained six *multiplicative compare* and four *vary* problems. The test administration procedures and conditions for the maintenance tests were identical to those of the baseline and post-intervention tests. To ensure that they would use their assigned strategy during the maintenance testing, students were provided with a brief review of the respective strategy immediately before the tests. Students 1, 2, and 3 completed all four tests during this phase, but Student 4 could not complete all of the tests because of a time conflict with his end of year test schedule. After all testing was completed, a satisfaction questionnaire was provided to the students.

Data Analysis

Visual analysis of the data was conducted to examine two overall aspects of the data: level (i.e., performance of students with learning disabilities on the word problem solving) and trend (i.e., changes or consistent patterns in the students' performance) within and between the phases (Tawney & Gast, 1984). Level changes between phases were identified based on the difference in the last data point value of the first phase and the first data point value of the next phase. Level changes within a phase were identified based on median or range as a mean level line of performance if variability is great (Cooper, Heron, & Heward, 1987). Specifically, if at least 80% of data points fall within a 15% value range of the mean level line, the data were considered stable and the mean level line acceptable (Tawney & Gast, 1984). Trend was determined by examining the direction of the data path related to whether it was flat, increasing, or decreasing. Split-middle lines were drawn within each phase to construct a trend line (Tawney & Gast, 1984).

CHAPTER 4

RESULTS

Successful mathematics performance is considered important to educational and occupational opportunities and most secondary schools require that all students take higher level mathematics to graduate (Chambers, 1994). However, students with LD experience more difficulties in mathematics than their peers without LD. Although a major emphasis of secondary school mathematics curricula is problem solving (Dossey, Mullis, Lindquist, & Chambers, 1988), students with LD frequently lack essential general problem solving skills and domain specific knowledge. They also exhibit deficits in executing specific mathematical strategies and fail to use self-regulation (Pressley, Symons, Snyder, & Cariglia-Bull, 1989). A number of studies have been conducted on the mathematical word problem solving performance of students with mathematics difficulties (i.e, Bottage, & Hasselbring, 1993; Case, Harris, & Graham, 1992; Cassel & Reid, 1996; Fuchs et al., 2004; Gleason et al., 1990; Hutchinson, 1993; Jitendra et al., 2002; Jitendra & Hoff, 1996; Jitendra et al., 1999; Jitendra & Xin, 1997; Maccini & Hughes, 2000; Montague, 1992; Montague et al., 1993; Moore & Carnine, 1989; Shiah et al., 1995; Walker & Poteet, 1989-90; Xin et al., 2005; Zawaiza & Gerber, 1993). These studies showed clear evidence that students with mathematics difficulties need to be provided with strategies before they can solve mathematical word problems successfully. Schema-based instruction has attracted the attention of researchers because more potential benefits in teaching mathematics problem solving to students with mathematics difficulties have been shown using this method (Fuchs et al., 2004; Hutchinson, 1993;

Jitendra et al., 2002; Jitendra et al., 1999; Xin et al., 2005). Schema is a general description of a group of problems that share a common underlying structure and require similar types of solutions (Chen, 1999; Gick & Holyoak, 1983). To teach schema understanding, four separate but interrelated problem solving procedural steps may be employed. The four steps are problem schema identification (or schema knowledge), representation (elaboration knowledge), planning (strategic knowledge), and solution (execution knowledge) (Marshall, 1995; Mayer, 1999). Schema-based instruction allows students to approach the problem by focusing on the underlying semantic or problem structure, thus facilitating conceptual understanding and adequate skills (Marshall, 1995). Four research questions guided this study: (a) To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after schema-based intervention?, (b) To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed by using the Mathematics Student Interest Inventory (Allsopp et al., 2008)?, (c) To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy to solve multiplication and division word problems?, (d) How will students with LD in grades 6-7 evaluate the effectiveness and acceptability of schema-based intervention?

A nonconcurrent multiple baseline (MB) design was used for the study. Four middle school students with LD participated in the pre-experimental (i.e., introduction, screening test, and Mathematics Interest Inventory session) and experimental (i.e., baseline, intervention, post-intervention test with generalization test, and maintenance test) session over a 13-week period. Participants were randomly assigned to a priori baseline durations (e.g., 6, 9, 12, 17 days) (Watson & Workman, 1981). All four students displayed stable responses during the baseline phase. During the intervention phase, students received 12 sessions of individual 30-35 minute schema-based intervention for 6 days (i.e., 2 sessions per day). Students participated in guided and independent practice and were encouraged to ask questions as they worked to master the material taught in each intervention session. During the post intervention phase, the four students' accuracy performance was evaluated by six untimed achievement or generalization tests developed by the researcher. The achievement and generalization tests contained a total of 10 one-step multiplication and division word problems. Out of the 10 problems, six problems were multiplicative compare (i.e., 2 problems per each subtype), and four were vary problems (i.e., 2 problems per each subtype). All of the students achieved scores greater than a pre-determined criterion level (i.e., 70% accuracy) on the six consecutive tests. Two weeks after termination of the post intervention phase, each student's accuracy performance on the achievement and generalization tests was examined during the follow-up maintenance phase.

In this chapter, the findings from each student's data are reported and used to address each research question. Systematic visual analysis was conducted to examine the stability, level change, and trend direction of the students' performance within and between the phases (Tawney, & Gast, 1984). Specifically, if at least 80% of data points fall within a 15% value range of the mean level line, the data were considered stable and the mean level line acceptable. Level changes between the phases were identified as the difference between the last data point value of one phase and the first data point value of the next phase. Trend was identified by examining whether the direction of the data path was flat, upward, or downward. Split-middle analysis was used to construct a trend line.

RESEARCH QUESTION 1

To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after schema-based intervention?

Research question 1 examined the effects of schema-based intervention on the students' accuracy performance on achievement tasks with one-step multiplication and division word problem solving. The students' accuracy percentage scores on the achievement tests during the baseline and post-intervention phases are shown in *Figure 4.1*. The students' average accuracy percentage scores on the achievement test during the baseline and intervention phases are presented in *Figure 4.2*. Each student's accuracy percentage scores for the word problem types on the achievement tests during the baseline and post-intervention phases are presented in Appendices D and E, respectively. Each student's accuracy performance on the achievement tests during the baseline and post-intervention phases is described in detail as follows.

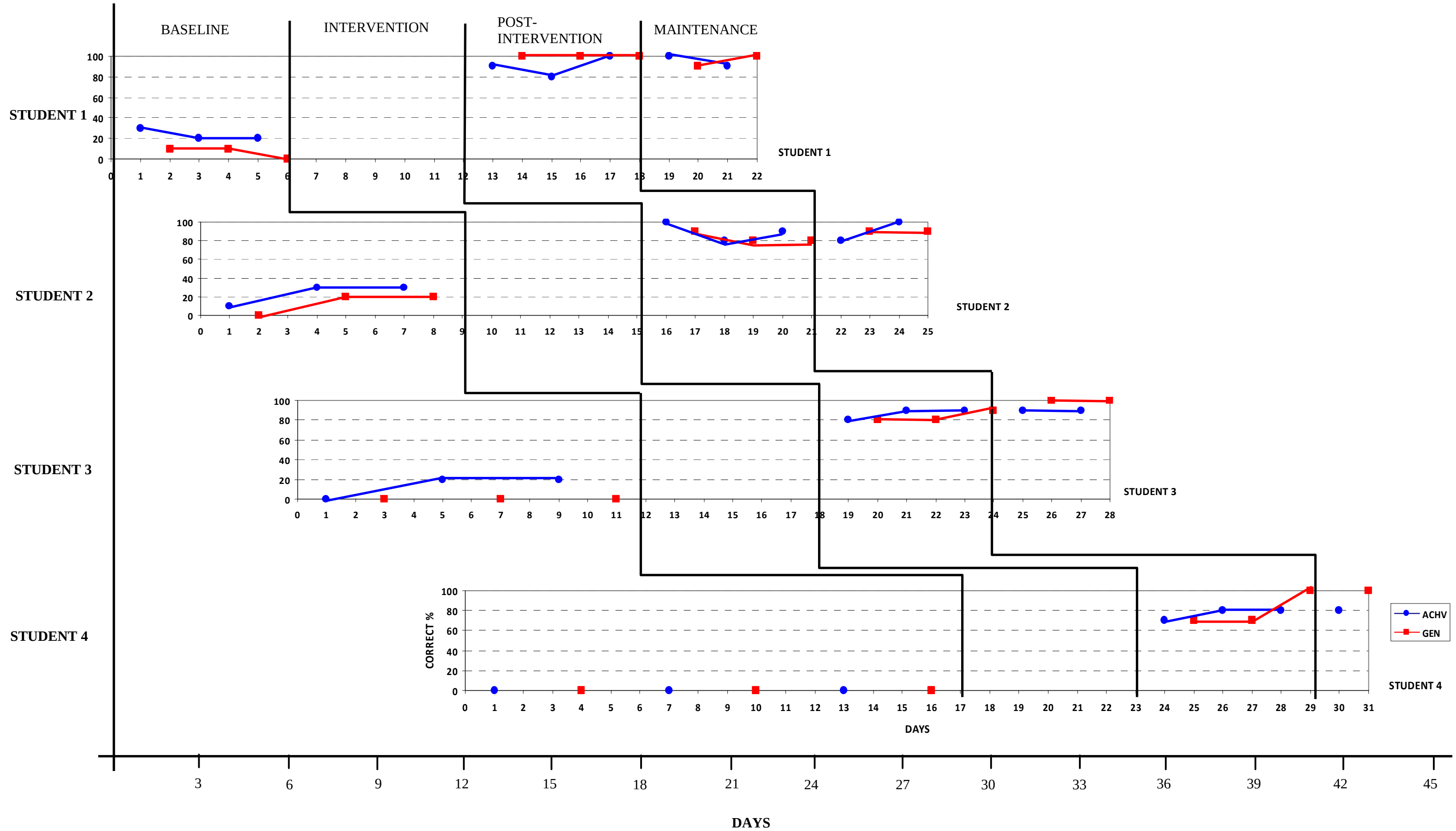


Figure 4.1. Accuracy Percentage Scores across Baseline, Post-intervention, and Maintenance phases for Students 1, 2, 3, and 4

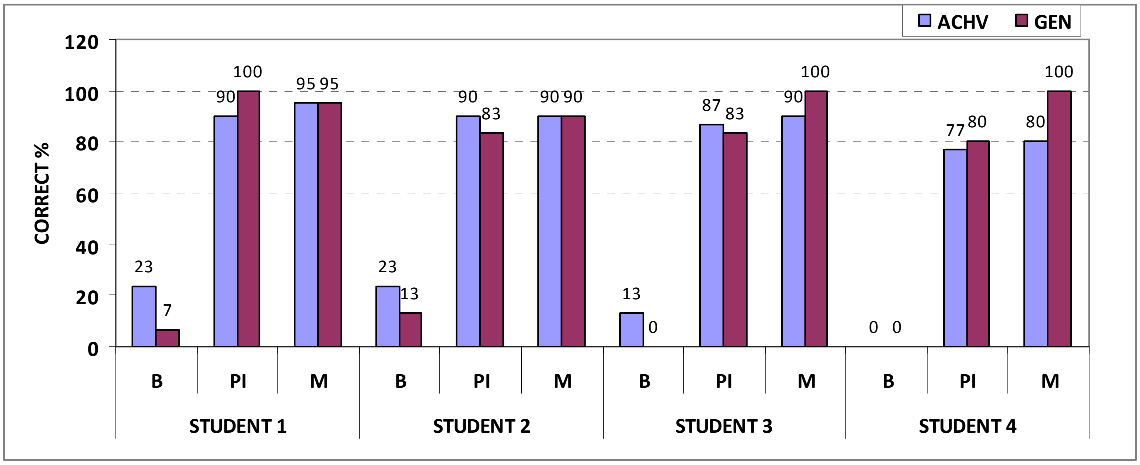


Figure 4.2. Overall Average Accuracy Percentage Scores across the Baseline (B), Post-intervention (PI), and Maintenance (M) Phases for Students 1, 2, 3, and 4

Student 1

Baseline. Student 1 received a total of six baseline sessions and took three achievement and three generalization tests for six days. Her accuracy percentage scores on the three achievement tests during the baseline phase were 30%, 20%, and 20%. As presented in Appendix D, Student 1 had correct answers for a *multiplicative compare/compared unknown* problem and two *vary/either of two dimensions unknown* problems on the first achievement test. She had correct answers for a *multiplicative compare/compared unknown* problem and a *vary/unit value unknown* problem on the second and third achievement tests. These baseline scores demonstrated that Student 1's accuracy performance on the achievement tests was stable and had a flat trend during the baseline phase. Her average accuracy percentage score on the achievement tests during the baseline phase was 23%.

Post-intervention. After Student 1 participated in 12 intervention sessions during six day periods, she took three achievement and three generalization tests. Student 1's accuracy percentage scores on the achievement tests showed an immediate increase in level from the last point of the baseline phase (i.e., from 20% to 90%). Her accuracy scores for the *multiplicative compare/referent unknown*, and both *vary/unit value unknown* and *vary/either of two dimensions unknown* problem types were 100% on the three achievement tests during the post-intervention phase. As presented in Appendix E, Student 1's accuracy performance remained stable (i.e., between 80% and 100%) and greater than the criterion level (i.e., 70% accuracy). Her average accuracy percentage score across the post-intervention phase was 90%.

Student 2

Baseline. On the fourth day after the start of Student 1's baseline phase, Student 2 had his first day of the baseline phase. Student 2 received a total of six baseline sessions and took three achievement and three generalization tests in a period of nine days. His accuracy percentage scores on the three achievement tests during the baseline phase were 10%, 30%, and 30%. As presented in Appendix D, Student 2 had a correct answer for the *multiplicative compare/compared unknown* problem on the first achievement test. He had correct answers for a *multiplicative compare/compared unknown,* a *multiplicative compare/referent unknown,* and a *vary/either of two dimensions unknown* problems on the second achievement test. On the third achievement test, he had correct answers for two *multiplicative compare/compared unknown* problems, and a *multiplicative compare/referent unknown* problem. These baseline scores demonstrated that Student 2's accuracy performance on the achievement tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the achievement tests during the baseline phase was 23%.

Post-intervention. After Student 2 received a total of 12 intervention sessions in six days, he also took three achievement and three generalization tests. As presented in Figure 4.1 Student 2's accuracy percentage scores on the achievement tests showed an immediate increase in level from the last point of the baseline phase (i.e., from 30% to 100%). His accuracy scores for both the *multiplicative compare* and *vary* problem type problems were 100% on the three achievement tests during the post-intervention phase. As showed in Appendix E, Student 2's accuracy performance remained stable (i.e., between 80% and 100%) and greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 90%.

Student 3

Baseline. On the fourth day after Student 2's baseline phase started, Student 3 had his first day of the baseline phase. Student 3 received a total of six baseline sessions and took three achievement and three generalization tests in a twelve day period. His accuracy percentage scores on the three achievement tests during the baseline phase were 0%, 20%, and 20%. As presented in Appendix D, Student 3 had correct answers for a *multiplicative compare/compared unknown* and a *vary/either of two dimensions unknown* problems on the second achievement test. He had correct answers for two *multiplicative compare/compared unknown* problems on the third achievement test. These baseline scores demonstrated that Student 3's accuracy performance on the achievement tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the achievement tests during the baseline phase was 13%.

Post-intervention. After Student 3 received a total of 12 intervention sessions for six days, he took three achievement and three generalization tests. As presented in Figure 4.1 Student 3's accuracy percentage scores on the achievement tests showed an immediate increase in level from the last point of the baseline phase (i.e., from 20% to 80%). His accuracy scores for the *multiplicative compare/referent unknown* and both *vary* problem type problems were 100% on the three achievement tests during the post-intervention phase. As shown in Appendix E, Student 3's accuracy performance remained stable (i.e., between 80% and 90%) and greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 87%.

Student 4

Baseline. On the seventh day after Student 3 started the baseline phase, Student 4 had his first day of the baseline phase. Student 4 received a total of six baseline sessions and took three achievement and three generalization tests within a seventeen day period. His accuracy percentage scores on the three achievement tests during the baseline phase were all 0%. As presented in Appendix D, Student 4 had no correct answer for any problem type even though he tried to solve each problem. Student 4's accuracy performance on the achievement tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the achievement tests during the baseline phase was 0%.

Post-intervention. After Student 4 received a total of 12 intervention sessions for six days, he took three achievement and three generalization tests. As presented in Figure 4.1 Student 4's accuracy percentage scores on the achievement tests showed an direct increase in level from the last point of baseline phase (i.e., from 0% to 70%). His accuracy scores for both the *multiplicative compare/compared unknown* and *referent unknown* problems were 100% on the three achievement tests during the post-intervention phase. As shown in Appendix E, Student 4's accuracy performance remained stable (i.e., between 70% and 80%) and greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 77%.

Summary of Results for Research Question 1

During the baseline sessions, each student's accuracy performance on the achievement tests remained stable and showed a flat trend. During the post-intervention sessions, visual inspection of the data revealed that each student's accuracy performance on the achievement tests immediately improved on the achievement tests, exceeding the criterion level of 70%. All four students' accuracy performance remained stable within each phase showing a flat trend with greater scores than the criterion level of 70%.

The improved accuracy percentage scores on the achievement tests showed that the students improved their performance on solving mathematical word problems after schema-based intervention. All four students achieved relatively higher accuracy percentage scores level for the *multiplicative compare/referent unknown, vary/unit value unknown*, and *vary/either of two dimensions unknown* problem types on the achievement tests. Specifically, average accuracy scores for those three problem types across the four students were 96%, 92%, and 96% respectively. However, the students achieved relatively lower scores for the *multiplicative compare/compared unknown*, and *multiplicative compare/scalar function unknown* problem types on the achievement tests. Specifically, average accuracy percentage scores for those two problem types across the four students were 83%, and 63%.

RESEARCH QUESTION 2

To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed by using the Mathematics Student Interest Inventory?

Research question 2 examined whether the effects of schema-based intervention generalized from the performance gains on the students' achievement tests to gain on the generalization tests developed by using the Mathematics Student Interest Inventory. Data on the students' accuracy performance on the generalization tests during the baseline and post-intervention phases are depicted in Figure 4.1. The students' average accuracy percentage scores on the generalization tests during the baseline and post-intervention phases are presented in Figure 4.2. Performance data for the word problem types on the generalization tests during the baseline and post-intervention phases are presented in Appendix D and E, respectively. Each student's performance on the generalization tests during the baseline and intervention phase is described as follows.

Student 1

Baseline. Student 1 received a total of six baseline sessions and took three achievement- and three generalization tests. Her accuracy percentage scores on the three generalization tests during the baseline phase were 10%, 10%, and 0%. As presented in Appendix D, Student 1 responded correctly to the *vary/unit value unknown* problem on the first and second generalization tests. These baseline scores on the generalization tests demonstrated that Student 1's accuracy performance was stable and showed a flat trend during the baseline phase. Her average accuracy percentage score during the baseline phase was 7%.

Post-intervention. After the intervention phase, Student 1 received a total of six post-intervention sessions and took three achievement and three generalization tests. As presented in Figure 1, Student 1's accuracy percentage scores on the generalization tests showed an immediate increase in level from the last point of the baseline phase (i.e., from 0% to 100%). Her accuracy scores for both the *multiplicative* and *vary* problem types were 100% on the three generalization tests during the post-intervention phase. As shown in Appendix E, Student 1's accuracy performance remained stable (i.e., 100%, 100% and 100%) and greater than the criterion level (i.e., 70% accuracy). Her average accuracy percentage score across the post-intervention phase was 100%.

Student 2

Baseline. Student 2 received a total of six baseline sessions and took three achievement and three generalization tests during the baseline phase. His accuracy percentage scores were 0%, 20%, and 20% on the generalization tests during the baseline phase. As presented in Appendix D, Student 2 responded correctly on a *multiplicative* *compare/compared unknown* and a *vary/either of two dimensions unknown* problems on the second generalization test. On the third generalization test, he had correct answers for two *multiplicative compare/compared unknown* type problems. These baseline scores demonstrated that Student 2's accuracy performance on the generalization tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the achievement tests during the baseline phase was 13%.

Post-intervention. After the intervention phase, Student 2 received a total of six post-intervention sessions and he took three achievement and three generalization tests. As presented in Figure 4.1 Student 2's accuracy percentage scores on the generalization tests showed an immediate increase in level from the last point of the baseline phase (i.e., from 20% to 90%). His accuracy score for the *multiplicative compare/referent unknown* type problems was 100% across the three generalization tests during the post-intervention phase. As reported in Appendix E, Student 2's accuracy performance remained stable (i.e., between 80% and 90%) and greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 83%.

Student 3

Baseline. During the baseline period, Student 3 received a total of six baseline sessions and took three achievement and three generalization tests. His accuracy percentage scores on the three generalization tests during the baseline phase were all 0%. As presented in Appendix D, Student 3 had no correct answers in terms of any problem type even though he tried to solve each problem. Student 3's baseline scores demonstrated that his accuracy performance on the generalization tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the generalization tests during the baseline phase was 0%.

Post-intervention. After the intervention phase, Student 3 received a total of six post-intervention sessions, and he took three achievement and three generalization tests. As presented in Figure 4.1 Student 3's accuracy percentage scores on the generalization tests showed a direct increase in level from the last point of the baseline phase (i.e., from 0% to 80%). His accuracy score for the *vary/either of two dimensions unknown* type problems was 100% across the three generalization tests during the post-intervention phase. As shown in Appendix E, Student 3's accuracy performance remained stable (i.e., between 80% and 90%) and greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 83%.

Student 4

Baseline. Student 4 received a total of six baseline sessions and took three achievement and three generalization tests in a period of seventeen days. His accuracy percentage scores on the three generalization tests during the baseline phase were all 0%. As presented in Appendix D, Student 4 had no correct answer in terms of any of the problem types even though he tried to solve each problem. Student 4's accuracy performance on the generalization tests was stable and had a flat trend during the baseline phase. His average accuracy percentage score on the generalization tests during the baseline phase was 0%.

Post-intervention. After the intervention phase, Student 4 received six post-intervention sessions and he took three achievement and three generalization tests. As presented in Figure 4.1 Student 4's accuracy percentage scores on the generalization tests showed an immediate increase in level from the last point of baseline phase (i.e., from 0% to 70%). His accuracy score for the *multiplicative compare/referent unknown* problems were 100% across the three generalization tests during the post-intervention phase. As shown in Appendix E, Student 4's accuracy performance showed increasing trend (i.e., 70%, 70%, and 100%) and remained greater than the criterion level (i.e., 70% accuracy). His average accuracy percentage score across the post-intervention phase was 80%.

Summary of Results for Research Question 2

Visual inspection of each student's accuracy percentage scores on the generalization tests revealed that each student's accuracy performance on the generalization tests remained stable showing qualitatively flat trend during the baseline phase. During the post-intervention sessions, visual inspection of the data revealed that each student's accuracy performance on the generalization tests immediately improved exceeding the criterion level (i.e., 70% accuracy) and students maintained those scores across the post-intervention phase.

The improved accuracy percentage scores on the generalization tests showed that the effectiveness of the schema-based intervention generalized to performance gains on the individualized generalization tests. All four students achieved relatively higher accuracy percentage scores for the *multiplicative compare/referent unknown* and *vary/either of two dimensions unknown* problem types on the generalization tests. Specifically, average accuracy scores for those two problem types across the four students were 96% and 92% respectively. In general, the students achieved relatively lower scores for the *multiplicative compare/compared unknown*, *multiplicative compare/scalar function unknown*, and *vary/unit value unknown* problem types on the generalization tests. Specifically, average accuracy percentage scores for those three problem types across the four students were 75%, 88%, and 84%.

RESEARCH QUESTION 3

To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy to solve multiplication and division word problems?

Research question 3 examined whether the schema-based intervention was effective in maintaining the students' accuracy performance on one-step multiplication and division word problem solving evaluated in the achievement and generalization tests. Data on the students' accuracy performance on the achievement- and generalization tests during the maintenance phase are presented on Figure 4.1. The students' average accuracy percentage scores on the achievement and generalization tests during the maintenance phase are depicted in Figure 4.2. Performance data for the word problem types on the achievement and generalization tests during the maintenance phase are presented in Appendix F. Each student's accuracy performance on the achievement- and generalization tests during the maintenance phase is described as follows.

Student 1

Maintenance. Two weeks after the post-intervention phase, Student 1 received four maintenance sessions and took two achievement- and two generalization tests during this phase. On the two achievement tests, her accuracy percentages scores were 100%, and 90%, which exceeded the criterion level. Those scores demonstrated that her intervention gains on the accuracy performance were maintained over time on the achievement tests showing a flat trend. On the two generalization tests, Student 1 achieved scores which exceeded the criterion level, demonstrating that she was also able to maintain the intervention gains over time with a flat trend on the generalization tests. Her accuracy percentage scores were 90%, and 100% on the generalization tests. Her average accuracy percentage scores for both the achievement and generalization tests were 95%.

Data on Student 1's accuracy performance for the word problem types on the achievement and generalization tests in Appendix F demonstrated that the student solved 100% of the problems correctly for the *multiplicative compare/compared unknown* problems*, vary/unit value unknown*, and *vary/either of two dimensions unknown* problems on both the achievement and generalization tests. Her accuracy percentage scores for the *multiplicative compare/referent unknown* on the achievement- and generalization tests were 100% and 75%, respectively. Her accuracy percentage scores for the *multiplicative compare/scalar function unknown* on the achievement- and generalization tests were 75% and 100% respectively.

Student 2

Maintenance. Student 2 received four maintenance sessions and took two achievement- and two generalization tests during the maintenance phase. On the two achievement tests, his accuracy percentages scores were 80%, and 100%, which exceeded the criterion level. Those scores demonstrated that his intervention gains on the accuracy performance were maintained on the achievement tests. On the two generalization tests, Student 2 achieved scores which exceeded the criterion level demonstrating that he was able to maintain the intervention gains over time on the generalization tests. He scored 90% in accuracy on both the generalization tests, and his average accuracy percentage score on the achievement and generalization tests combined was 90%.

Data on Student 2's accuracy performance for the word problem types on the achievement- and generalization tests in Appendix F demonstrated that the student solved 100% of the problems correctly for the *multiplicative compare/scalar function unknown*, *vary/unit value unknown*, and *vary/either of two dimensions unknown* problems on both the achievement and the generalization tests. His accuracy percentage scores for the *multiplicative compare/compared unknown* problems on the achievement- and generalization tests were 75% and 50%, respectively. His accuracy percentage scores for the *multiplicative compare/referent unknown* problems on the achievement- and generalization tests were 75% and 100% respectively, which shows a flat trend.

Student 3

Maintenance. Student 3 received four maintenance sessions and took two achievement and two generalization tests during the maintenance phase. On the two achievement tests, his accuracy percentages scores were both 90%, which exceeded the criterion level. Those scores demonstrated that his intervention gains in accuracy performance were maintained on the achievement tests. On the two generalization tests, Student 3 achieved scores which exceeded the criterion level, demonstrating that he was able to maintain the intervention gains over time on the generalization tests as well. His accuracy percentage scores were 100% on both of the generalization tests. His average accuracy percentage score for the achievement and generalization tests were 90% and 100%, respectively.

Data on Student 3's accuracy performance for the word problem types on the achievement and generalization tests in Appendix F showed that the student solved 100% of the problems correctly for the *multiplicative compare/referent unknown, multiplicative compare/scalar function unknown*, *vary/unit value unknown*, and *vary/either of two dimensions unknown* problems on both the achievement and generalization tests. His accuracy percentage scores, which showed a flat trend, for the *multiplicative compare/compared unknown* problems on the achievement- and generalization tests were 50% and 100%, respectively.

Student 4

Maintenance. Student 4 received two maintenance sessions and took one achievement and one generalization test during the maintenance phase. On the achievement test, his accuracy percentages score was 80%, which exceeded the criterion level, even though this single score could not demonstrate that his intervention gains on the accuracy performance were maintained over time on the achievement tests. On the generalization tests, Student 4 achieved a score of 100% which exceeded the criterion level. However, this one time score could not show whether he was able to maintain the intervention gains over time on the generalization tests.

Data on Student 4's accuracy performance for the word problem types on the achievement and generalization tests in Appendix F demonstrated that the student achieved a score of 100% correct for the *multiplicative compare/compared unknown*, *vary/unit value unknown*, and *vary/either of two dimensions unknown* problems on both the achievement and the generalization tests. His accuracy percentage scores for the *multiplicative compare/referent unknown* problems on the achievement- and generalization tests were 50% and 100%, respectively. His accuracy percentage scores, which showed a flat trend for the *multiplicative compare/scalar function unknown* problems on the achievement- and generalization tests were 50% and 100% respectively.

Summary of Results for Research Question 3

During the maintenance phase, performance data on the achievement- and generalization tests showed that three out of four students maintained their intervention gains on their accuracy performance. An analysis of the data on the average accuracy percentage scores demonstrated that the increased average scores for the students on the achievement- and generalization tests during the maintenance phase were as high as or greater than those achieved during the post-intervention phase. A comparison of the data during the maintenance phase between the achievement- and generalization tests revealed that the average accuracy percentage scores on the generalization tests were as high as or greater than those on the achievement tests.

All four students had accuracy percentage scores of 100% for the vary problem type but had relatively lower scores for the multiplicative compare problem type on the achievement and generalization tests during the maintenance phase. Specifically, on the achievement tests, the average accuracy scores for the *multiplicative compare/compared unknown, referent unknown,* and *scalar function unknown* problem types across the four students were 69%, 81%, and 81%, respectively. On the generalization tests, those average percentage scores across the four students were 88%, 94%, and 100%, respectively.

RESEARCH QUESTION 4

How will students with LD in grades 6-7 evaluate the effectiveness and acceptability of schema-based intervention?

Results of the strategy satisfaction questionnaire indicated that all four students were satisfied with the strategy in terms of seven items. In the first part of the modified questionnaire, a Likert-type scale of 1 (strongly disagree) to 5 (strongly agree) was used for the students to provide information about whether about whether (a) they enjoyed the intervention, (b) the strategy was helpful in solving word problems, (c) their word problem solving skills were improved, (d) they would recommend using the strategy with their peers, (e) they would continue to use it to solve word problems in the classroom, and (f) they were satisfied with the strategy overall. The overall mean ratings of the four students for each item were 4.3 (i.e., range = 4~5) for *enjoy*, 5 (i.e., all students evaluated scale 5) for *helpful*, 4.5 (i.e., range = 4~5) for *improve*, 4.8 (i.e., range = 4~5) *recommend using*, 4.8 (i.e., range = 4~5) *continue to use*, and 4.5 (i.e., range = 4~5) for *satisfy* items, respectively.

In the second part of the questionnaire, the students' comments related to the suggestions about the strategy indicated that they liked solving the word problems. Their answers varied form "I liked the new strategy. It was so fun and learned a lot. She helped me learn how to do this. Really liked coming with her!" to "I wasn't really good at math and solving math problems but I got better at it because of the strategies you taught me," and "I feel happy with solving the math word problems."

SUMMARY

The results of this study revealed that all four students were able to use the schema-based strategies to solve the multiplication and division word problems and improve their accuracy performance on the achievement tests. During the post-intervention phase, the students attained the scores that exceeded the criterion level on the achievement tests, and maintained those scores for the reminder of the post-intervention phase. As shown on the achievement tests, the students achieved the scores that exceeded the criterion level on the generalization tests during the post-intervention phase and three of the four students maintained those scores for the reminder of the post-intervention period. Two weeks after the post-intervention phase, all four students successfully maintained their improved accuracy performance on the achievement and generalization tests during the maintenance phase. Student 4 took one achievement and one generalization test during the maintenance period. Although his single score could not demonstrate that his intervention gains on the accuracy performance were maintained over time on the achievement tests and generalization tests, his scores exceeded the criterion level. All four students were satisfied with the strategy in general.

CHAPTER 5

DISCUSSION

The purpose of this study was to examine the effectiveness of schema-based intervention on the mathematical word problem solving skills of four middle school students with LD in grades 6-7. Results of this study showed that middle school students with LD in this study could be taught to improve their skills to solve one step multiplication and division word problems by applying schema-based strategies. This chapter describes the major findings of the study pertaining to the four research questions and present conclusions drawn from the findings. Limitations of the study and implications for practice and future research are provided as well.

RESEARCH QUESTION 1

To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after schema-based intervention?

In this study, the four students' performance substantially improved after they received the intervention. All four students achieved scores that exceeded the criterion level (70% accuracy) on the achievement tests during the post intervention phase. These findings provide empirical evidence that schema-based intervention is effective in teaching middle school students with LD to solve multiplication and division word problems. During the baseline phase, the students simply added the numbers in the problem without understanding the problem or multiplied the numbers using the provided calculator without making complete number sentences. However, the data on the students' performance suggest that they were able to improve their performance on word problem solving using multiplication and division after they learned how to solve two types of word problems using the schema-based strategies. During the intervention phase, they had guided and independent practice sessions. Students followed each step of the schema-based strategies to find the problem type, organize the information in the problem using the diagram, translate the information in the diagram into a math equation, solve the equation, and write the complete answer. In addition, students had a chance to check whether the answer made sense. The researcher gave them instant feedback for mastery learning. Improved academic performance between the baseline and post-intervention phases suggested that the students became much more proficient at solving multiplicative compare and vary word problems. These findings are consistent with previous research on schema-based intervention for students with LD (e.g., Fuchs, Fuchs, Finelli, et al., 2004; Jitendra et al., 1998; Jitendra & Hoff, 1996; Jitendra et al., 1999; Xin et al., 2005; Zawaiza & Gerber, 1993).

Instructional Features of the Intervention

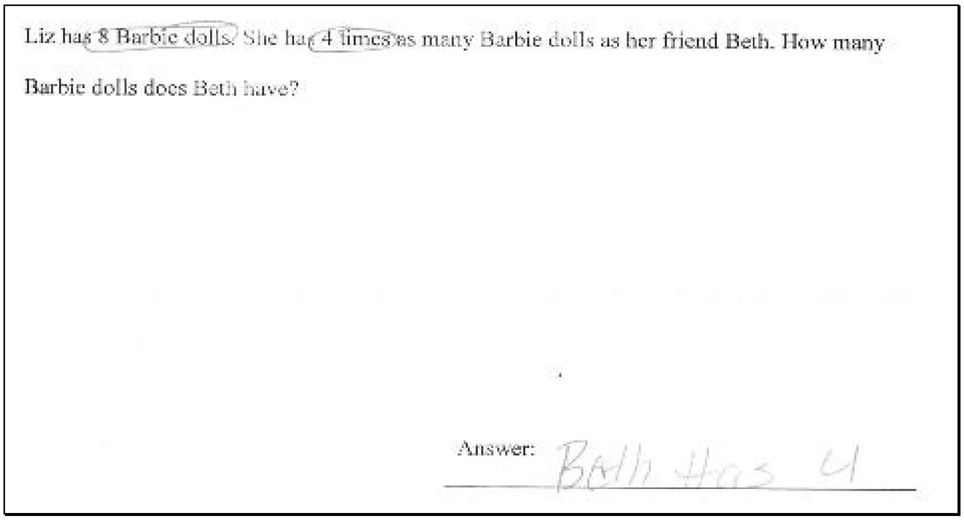
Some of the instructional features of schema-based intervention may be possible factors that account for the results of this study. First, the explicit instructional modeling embedded in the schema-based strategies systematically taught students the structure of different problem types including multiplicative compare and vary problems. For example, explicit instructional modeling with the checklist helped students become familiar with the use of the strategies, and the schematic diagrams for multiplication and division problems in this study cheated a direct link between the problem schema representation and its solution. Research has shown that the use of explicit instruction helps students understand the underlying structure of the problems so that students can successfully master mathematical concepts and problem solving skills (Hutchinson, 1993; Jitendra & Hoff, 1996; Marsh & Cooke, 1996; Zawaiza & Gerber, 1993; Jitendra et al., 2002; Xin et al., 2005).

Second, the advance organization embedded in the strategy intervention may provide students with a structure for new information and relate it to information that the students already possess. For example, after introducing the two types of word problems, the components of each type of word problem were reviewed and explained by the researcher and then students were asked to verbalize characteristics of the word problem type during the remainder of the intervention session. The advance organization factor helped students to relate each problem type to each diagram and apply the relationship they found between the information in the problem type and the diagram to understanding the structure of the practice problems. The finding that advance organization enhances intervention outcomes is consistent with the existing literatures (Rosenshine, 1995; Swanson, & Deshler, 2003).

Third, the 30 to 40 minutes of one-to-one instruction time during each intervention session provided students with guided and independent practice, individual tutoring, and individually paced instruction. For example, guided and independent practice sessions during the intervention session included corrective and instructional feedback and gave opportunities for students to practice solving word problems by applying the strategies on their own. Individual tutoring made it possible for the students to receive individually paced instruction and adequate feedback based on their individual needs. One-to-one instruction that includes guided and independent practice opportunities has been suggested as an essential component of mathematics instruction for students with learning disabilities (Wasik & Slavin, 1993; Elbaum, Vaughn, & Hughes, & Moody, 2000). This study corroborates the findings of previous research on the schema-based strategies, which suggest that strategy intervention is essential for enhancing the mathematical word problem solving skills of students with learning disabilities.

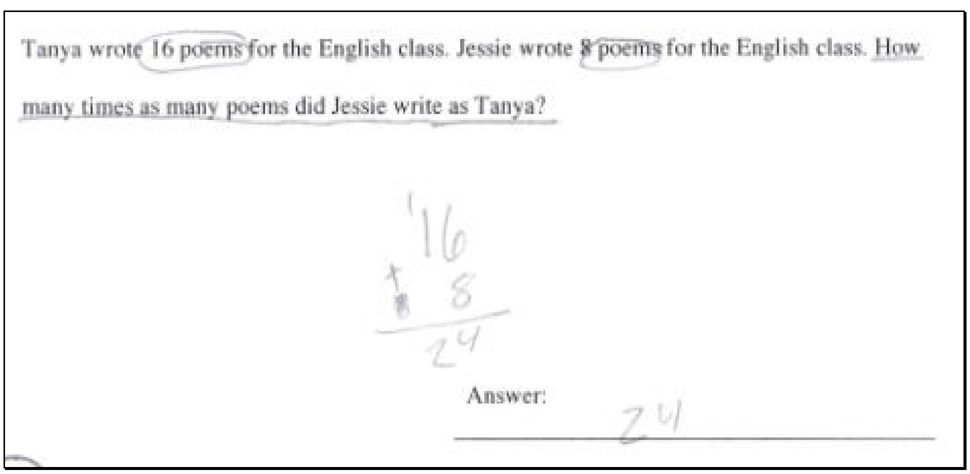
Performance Characteristics

In addition, several performance characteristics shown by the students may also be suggested as important factors that explain the students' improved accuracy performance level on the achievement tests. First, the students' improved representation skills may be related to their fast improvement on their word problem performance. At the beginning of the intervention phase, all the students used immature strategies to solve the problems for multiplication and division and gradually shifted towards the advanced representation strategies (e.g., Step 1 find the problem type, Step 2 Organize the information in the problem using each problem diagram). For example, Student 1 just circled the numbers and labels in the problem and wrote her answer (see Figure 5.1), or simply added up the numbers she circled by using the provided calculator (see Figure 5.2) during the baseline. After the intervention, she showed her representation skills on the multiplication and division problem and correctly wrote a question mark for what must be solved (see Figures 5.3 and 5.4). Consequently, she improved her representation and problem solving performance rate and was able to achieve 90% correct on the first achievement test after the intervention. She then stabilized to consistently scoring between 80% and 100% correct on the achievement tests during the post-intervention phase.


Liz has 8 Barbie dolls. She has 4 times as many Barbie dolls as her friend Beth. How many Barbie dolls does Beth have?

Answer: Beth Has 4

Figure 5.1. Student 1's circling during the baseline phase


Tanya wrote 16 poems for the English class. Jessie wrote 8 poems for the English class. How many times as many poems did Jessie write as Tanya?

$$\begin{array}{r} 16 \\ +\ 8 \\ \hline 24 \end{array}$$

Answer: 24

Figure 5.2. Student 2's adding up during the baseline phase

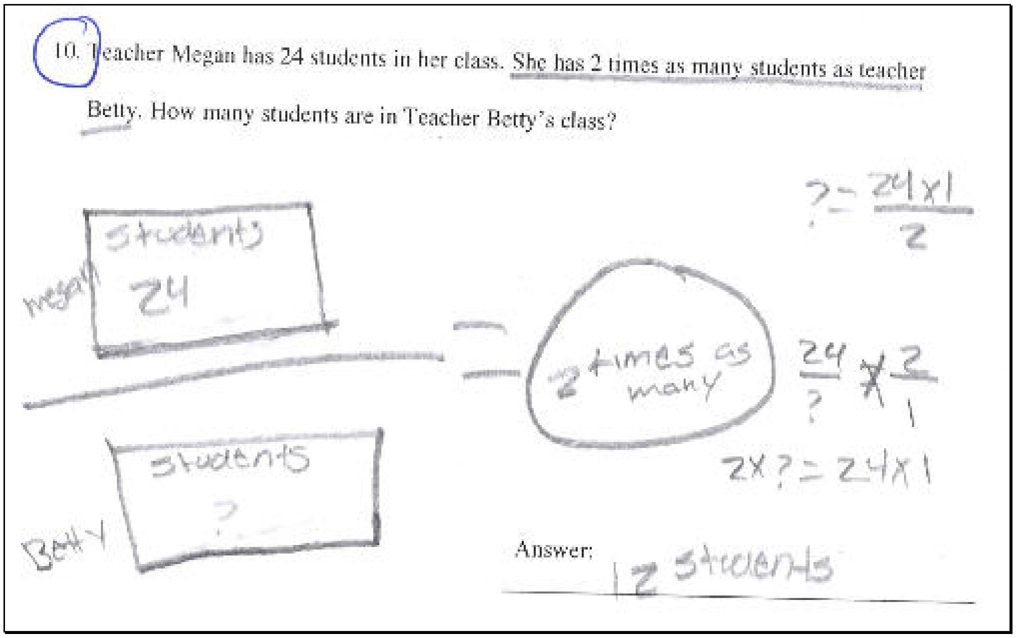


Figure 5.3. Student 1's MC problem representation during the post-intervention phase

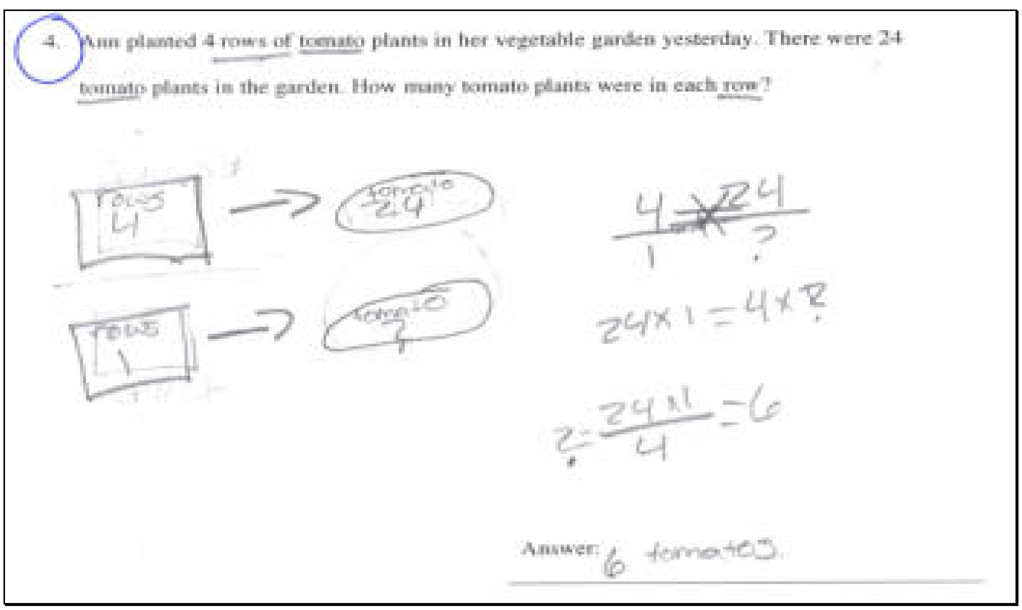


Figure 5.4. Student 1's Vary problem representation during the post-intervention phase

On the other hand, the performance levels and trends in Student 4's accuracy percentage scores across the phases were relatively different from those of the other students. In the baseline phase, he just added up all the numbers in the problem using the calculator and always said "easy" when the researcher asked whether the problem was easy or difficult. In the first achievement test after the intervention he received 70%, which was the criterion score and got between 70% and 80% correct scores during the post-intervention phase. However, it was observed that he often spent 1 to 1.5 hours to complete each step on the achievement test, which usually took the other students only 30 to 45 minutes. It was also observed that he sometimes lost track of where he was in the steps he was supposed to follow to solve the problems. His relatively low achievement scores may be due to the use of slow and immature strategies. Previous research on the mathematical performance of students with learning disabilities has revealed that students with learning disabilities frequently use slower and more immature strategies to solve the problems (Geary, 1990, 1994; Geary et al., 2000).

Second, the students' reading competency may also be an important factor affecting their improvement on accuracy performance. According to their grade reports, Students 1, 2, and 3 had above average reading skills and Student 4 had below average reading scores in their resource reading classes. The students' performance data showed that Students 1, 2, and 3 achieved relatively higher scores than Student 4 during the post-intervention phase. Although all the students achieved scores above the criterion, Student 4 took longer to read problems and achieved relatively lower scores than the other students during the post-intervention phase. This might be explained by previous research showing that mathematics performance and reading skills are closely related (i.e., Fuchs & Fuchs, 2002; Geary et al., 2000; Jordan et al., 2003; Jordan, & Montani, 1997; Silver et al., 1999).

Third, the students' improvement on the accuracy performance may be related to their positive attitude toward the intervention and motivation. For example, it was observed that Students 1 and 2 never showed any behavioral and attention problems when they worked on the intervention. Student 1 wrote check marks on the checklist in order to distinguish between what she had done and was going to do even though writing check marks was not something the students were taught to do during the intervention. The researcher always encouraged the students to do their best and gave them verbal rewards during the intervention sessions. Such attention and encouragement may have helped the students work hard during each intervention session and consequently may have influenced the students' overall improvement on the accuracy performance.

Showing the same positive learning attitude, Students 3 and 4 also achieved immediate improvement on the accuracy performance during the post-intervention phase. However, during the intervention phase, it was observed that Student 3 seemed to be easily distracted by the environment even though the place the intervention was carried out was quiet and originally designed for one-to-one tutoring in the school's drop-out prevention program. In an informal interview with his resource class teacher, she mentioned that Student 3 has behavioral problem and does not want to do anything in her class. The dropout prevention specialist who had observed the relationship between the resource teacher and Student 3 pointed out that there has been tension between them.

However, no statements about the behavioral problems were found in his IEP, and Student 3 said that he likes his resource teacher but that she does not want to listen to his opinion. Despite theses issues, he continued to improve through the intervention sessions with the researcher's encouragement, and was proud of himself when he achieved over 80% correct though the post-intervention phase.

The main problem the researcher had when working with Student 4 at first was making eye contact with him. He avoided eye contact even though his IEP did not mention any social or behavioral problems. Like Student 3, Student 4 got better during the intervention phase with the researcher's encouragement and verbal rewards. He enjoyed later intervention sessions more and showed confidence and positive attitude towards learning. He was also proud of himself when he got 70% correct in the first achievement test in the post-intervention phase.

Similar findings about students' attitude and their achievement have been found in previous studies with students with learning disabilities. For example, Yasutake and Bryan (1995) found that repeated failure and negative interactions places students at great risk for experiencing negative affect, which transforms into poor academic self-concept, low expectations of future academic performance, attribution of failure to low ability, and attribution of success to external factors, all of which are characteristic of students with learning disabilities (Licht, 1993). According to other studies conducted with middle school students with learning disabilities (Montague, 1992; Montague & Applegate, 1993; Montague, Bos, & Doucette, 1991), the students with learning disabilities generally indicated a positive attitude toward math, clearly demonstrated a low academic self-concept when compared with higher achieving peers, and viewed mathematical problem solving as important.

RESEARCH QUESTION 2

To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed using the Mathematics Student Interest Inventory?

As the results on the achievement tests demonstrate, each student's accuracy performance immediately increased over time during the post-intervention phase. All four students were able to achieve scores that exceeded the criterion level on the generalization tests. Their improved accuracy percentage scores on the generalization tests demonstrated that the effectiveness of the schema-based intervention generalized from the gains on the achievement tests to those on the generalization tests. These positive benefits may be attributed to the personalized contexts of the generalization tests that included information identified from the Mathematics Student Interest Inventory (Allsopp et al., 2008). This finding is consistent with the study about the impact of both personalizing mathematical word problems and rewording them for explicitness (i.e., Davis-Dorsey, Ross, & Morrison, 1991) in that personalization made the problems more motivating, made it easier to construct a meaningful conceptual representation to connect the problem information and solution strategies, and helped with successful encoding and retrieval. The personalization employed was similar to that used for this present study in that personalization was achieved by incorporating information about the individual learner in the general contexts and specific referents presented in the word problems

(Davis-Dorsey et al., 1991). The finding that students benefit from instruction and assessment that occurs within authentic contexts has been suggested in a lot of research (e.g., Bottage, 1999; Bottage et al., 2003; Bottge et al., 2002; Gersten, 1998; Schumm et al., 1995; Wehmeyer, et al., 1998). In fact, in the present study, all the students seemed to be surprised by the appearance of the familiar names and items they had shared with the researcher on the generalization tests. The students seemed to enjoy solving the problems and sometimes asked how the researcher knew their friends' names and what they liked. This may account for the students' working faster to complete problems on the generalization tests than on the achievement tests. For example, Student 2 often said that this was the first time he had seen his name in word problems because he has a unique name, and he liked to solve the problems that included his name. He was more likely to solve these problems quickly on the generalization tests.

A comparison of each student's data points on the accuracy performance on the achievement and generalization tests revealed that the improvement level of each student's accuracy percentage scores was similar between on the generalization tests and on the achievement tests during the post-intervention phase. This finding is confirmed by the graphs in Figure 4.2 showing that the average accuracy percentage scores of all the students on the generalization tests (i.e., 86.5%) were similar to their scores on the achievement tests (i.e., 86%) during the post-intervention phase. Even though the researcher expected that all the students would gain higher scores on the generalization tests than on the achievement tests, Students 2 and 3 gained lower scores on the generalization tests than on the achievement tests. It may be that these students were distracted by the familiar information included in the problems on the generalization tests.

In addition, an analysis of data on each word problem type revealed that all four students achieved relatively higher accuracy percentage scores for the *multiplicative compare/referent unknown*, and *vary/either of two dimensions unknown* problem types both on the achievement and generalization tests (i.e., 96%, 96%, 96%, and 92%, respectively). At the same time, the students achieved relatively lower scores for the *multiplicative compare/compared unknown*, and *multiplicative compare/scalar function unknown* problem types both on the achievement and generalization tests (i.e., 83%, 63%, 75%, and 88%, respectively). This may simply be because the students found the *multiplicative compare/compared unknown* and *multiplicative compare/scalar function unknown* problem types more difficult.

RESEARCH QUESTION 3

To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy to solve multiplication and division word problems?

During the maintenance phase, each student's data points on the accuracy performance on the achievement and generalization tests showed that all four students successfully maintained their intervention skills. An analysis of their average accuracy percentage scores revealed that the scores of the students during the maintenance phase (i.e., M = 88.8%) were slightly greater than those achieved during the post-intervention phase (i.e., M = 86%). In addition, during the maintenance phase a comparison between the achievement and generalization test scores revealed that the average accuracy percentage scores on the generalization tests were greater than those on the achievement tests (i.e., M = 96.3%, 88.8%, respectively).

The number of intervention sessions may be suggested as a factor to explain why all the students maintained their improved accuracy percentage scores during the maintenance phase. In this study, each student received twelve individual 30-35 minutes intervention session three to five times a week over a period of three weeks. This finding was consistent with the suggestion of the previous research that a twelve intervention sessions are necessary for students with learning disabilities to acquire mathematical word problem skills (Jitendra et al., 2002).

The short interval between the intervention and maintenance phases may be another factor explaining why the students' skills were maintained after their intervention gains. Considering that four weeks was recommended as an appropriate interval between the intervention and follow-up phases (Xin & Jitendra, 1999), the two week intervals between the intervention and maintenance phases might have affected to the maintenance effect of this study. While Students 1, 2, and 3 were provided with four maintenance sessions two weeks after terminating the intervention phase, due to the time constraints of the study. Student 4 had only two maintenance sessions less than two weeks after the intervention phase. Thus, the findings indicate that short intervals between the intervention and maintenance phases helped the students maintain the word problem solving knowledge and skills obtained during the intervention phase.

RESEARCH QUESTION 4

How will students with LD in grades 6-7 evaluate the effectiveness and acceptability of schema-based intervention?

Results of the strategy satisfaction questionnaire indicated that all four students evaluated the strategy as enjoyable and helpful. All the students further showed their willingness to recommend using the strategy to their peers and to continue to use it to solve word problems in the classroom. They also evaluated that the overall process of the strategy was satisfactory. The students' positive evaluation after the maintenance phase might be attributed to the students' achievement on the mathematical word problems and their positive attitude toward learning to solve mathematical word problems.

According to Montague (1997), students with learning disabilities usually demonstrate poor self-perceptions of their performance in mathematics and mathematical problem solving performance. Feelings of helplessness and low self-worth as well as maladaptive attributional beliefs, which are reinforced by new failure experience may be caused by early and numerous failures in school. Recognizing the interrelation between students' self-perception of the performance and their achievement, it might be natural that students with learning disabilities are poor problem solvers. In fact, toward the beginning of the intervention, the students said several times that they were not good at mathematics and needed to learn how to solve problems. The positive evaluation of the intervention by the students with learning disabilities in the present study might show that their perception of their own mathematical performance was changed during this study due to their visible improvement through the intervention.

LIMITATIONS OF THE RESEARCH

Although the results indicated that the schema-based intervention improved students' mathematical word problem solving skills, several limitations of the study suggest that caution must be exercised when interpreting the findings. First, only four students participated in the study in the individual setting. Therefore, even though the study showed the effectiveness of the schema-based intervention for those four students, generalizing the findings to another student population may be limited.

Second, this study did not occur during the regularly scheduled math period in the school. Even though this study was occurred during the students' tutoring program, which the middle school has run already as a dropout prevention program, students had to be pulled out from their resource classes for this study. As a result, caution must be noted in generalizing study findings to special educational students in the general education inclusion mathematics courses. Extending this study to special education students in inclusive settings is an area that needs further investigation.

Third, the students individually received the intervention by the researcher in each intervention session. The researcher's considerable attention and encouragement in the individual intervention setting was based on carefully designed instruction and increased focus on the two problem types, which may have influenced the students' performance, instead of the specific schema-based nature of the instruction.

The use of a non-standardized testing instrument for the screening, achievement, generalization and maintenance tests is the fourth limitation. The tests that were used to assess students' performance included a total of 10 one-step multiplication and division text-based word problems. Data collected with non-standardized instruments are susceptible to systematic errors that inflate or deflate performance and unsystematics errors that produced by factors within the participants such as motivation, conditions of test administration, and changes in the measurement instrument or task (Mertens, 1998).

Lastly, social validity was not adequately assessed in the study with the teachers. Strategy satisfaction questionnaire with the students was conducted in the study, thus, student perspectives of the effectiveness and acceptability of the schema-based intervention were obtained. However, without the formal or informal interviews with the teachers the students’ progress on the mathematical performance in the areas of word problem solving, multiplication, and division in the regularly scheduled math classroom could not be determined. A replication study is suggested to examine teachers’ perspectives of the effectiveness and acceptability of the schema-based intervention with their suggestions with the overall intervention procedures.

IMPLICATIONS FOR PRACTICE

The findings from this study have several implications for practice. First, with its emphasis on conceptual understanding, the schema-based intervention helped students with learning disabilities not only acquire mathematical word problem solving skills but also maintain the taught skills. Students with learning problems in mathematics are often lacking in basic mathematical skills, and as a result, teachers are likely to spend more time in teaching them how to do calculations rather than focusing on instruction that enhances their conceptual understanding of how to approach problems (Lester, 1989). Therefore, mathematics curriculum, especially for the students with learning problems in mathematics, should focus more attention on explicitly teaching the students schema-based strategies and providing them with opportunities to solve assorted kinds of problems to ensure that students grasp the underlying structure of the problems.

Second, the effectiveness of the schema-based strategy instruction in this study suggests that students with learning disabilities are able to learn strategies about how to identify the relationship present in each word problem. Lack of attention, organization, and working memory are the characteristics of many students with learning disabilities, which demonstrates that they are often cognitively disadvantaged (Gonzalez & Espinel, 1999; Zentall & Ferkis, 1993). Furthermore, creating complete and accurate mental problem representation is an accompanying difficultiy from their cognitive disadvantages (Lewis, 1989; Marshall, 1995). To overcome those disadvantages, it is essential that teachers provide students with learning disabilities with scaffolds, such as schema diagrams which help students organize information in word problems, reduce students' cognitive load, and enhance working memory by directing resources to correctly set up the math equation and facilitate problem solution when teaching conceptual understanding of key features of the problem (Xin et al., 2005). Such diagrams allow students to directly transform the diagrammatic representation into an appropriate math equation and check the accuracy of their answer.

Third, the effectiveness of the strategy when implemented by the researcher may indicate the importance of researchers' collaborating with teachers who are willing to invest efforts in continuing to learn and use a strategy that had beneficial effects for their students. According to Thompson (1989), to provide students with the strategy instruction in mathematical problem solving, teachers are required to be knowledgeable about the strategies, confident about teaching the strategies, knowledgeable about the learners, and aware of how to plan classroom activities that are helpful to mathematical word problem solving. Additionally, it is important for teachers to adapt instruction to each individual's unique needs and provide students with appropriate instructional support. Professional development, pre-service and in-service teacher education need to include curriculum about teaching strategies for solving mathematical word problems.

IMPLICATIONS FOR FUTURE RESEARCH

Several suggestions for future research have emerged from the analysis of the findings of this study. First, to validate the results of this study, it is recommended that this study be replicated not only in the resource setting but also in other educational settings (e.g., inclusive classrooms) in which mathematical word problem solving instruction is provided for students with learning problems in mathematics. This study was conducted with individual students in a pull-out setting. Therefore, the promising outcomes of the schema-based strategy intervention can be more generalized by extending the settings into varied settings not only in school settings but also out of school settings

Second, an investigation of the effects of the schema-based intervention is needed to be conducted with various combinations of classroom settings (e.g., small group setting in resource classroom, large group setting in resource classroom, small group setting in inclusive classroom, and large group setting in inclusive classroom etc.). Be varying the group settings, the suspicious factor that the researcher's considerable attention and encouragement in the individual intervention setting based on the generally carefully designed instruction instead of the specific schema-based nature of the instruction can be lessen, and as a result, the effects of the intervention can be more generalized.

Third, to examine feasibility of the schema-based intervention in the classroom, a further study needs to be conducted with an emphasis on the teachers' perspectives of the effectiveness and acceptability of the schema-based instruction. Even though the strategy satisfaction questionnaire with the students was implemented in this study, without the formal or informal information obtained from the teachers, it was not possible to assess whether the students' made similar progress on their mathematical performance in the taught areas in the general classroom or whether the students continued to use the strategies, and apply them to another problems. A replication study that includes an examination of both teachers and students' perspectives of the effectiveness and acceptability of the schema-based intervention is needed.

Lastly, a study assessing students' affect is needed with the study about the effectiveness of the schema-based intervention. Recognizing the interrelation and interaction between affect and cognition underscores the need to access not only children's ability and achievement but also their affective states with respect to academic and social experiences, assessing students attitudes, beliefs, emotions, and perceptions using a variety of techniques such as interviews, questionnaires, and informal dialogues is suggested to identify affective factors that may negatively or positively influence performance and behavior (Montague, 1997).

SUMMARY

The purpose of this study was to examine the effectiveness of schema-based intervention on the mathematical word problem solving skills of middle school students with LD in grades 6-7. A nonconcurrent multiple baseline (MB) design was used for the study. Four middle school students with LD participated in the pre-experimental (i.e., introduction, screening test, and Mathematics Interest Inventory session) and experimental (i.e., baseline, intervention, post-intervention test with generalization test, and maintenance test) session over a 13-week period. Participants were randomly assigned to a priori baseline durations (e.g., 6, 9, 12, 17 days) (Watson & Workman, 1981). All four students displayed stable responses during the baseline phase. During the intervention phase, students received 12 sessions of individual 30-35 minute schema-based intervention for 6 days (i.e. 2 sessions per day). Students participated in guided and independent practice and were encouraged to ask questions as they worked to master the material taught in each intervention session. During the post intervention phase, the four students' accuracy performance was evaluated by six untimed achievement or generalization tests developed by the researcher. The achievement and generalization tests contained a total of 10 one-step multiplication and division word problems. Out of the 10 problems, six problems were multiplicative compare (i.e., 2 problems per each subtype), and four were vary problems (i.e., 2 problems per each subtype). All of the students achieved scores greater than a pre-determined criterion level (i.e., 70% accuracy) on the six consecutive tests. Two weeks after termination of the post intervention phase,

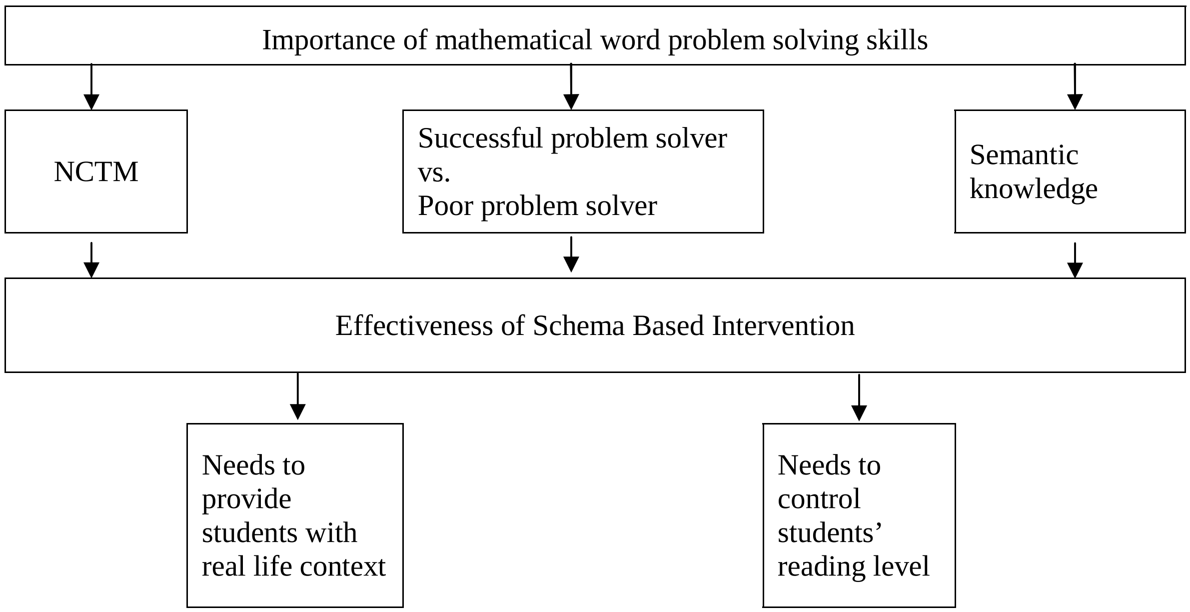
each student’s accuracy performance on the achievement and generalization tests was examined during the follow-up maintenance phase.

The results of this study revealed that all four students were able to use the schema-based strategies to solve the multiplication and division word problems and improve their accuracy performance on the achievement tests. During the post-intervention phase, the students gained the scores that exceeded the criterion level on the achievement tests, and maintained those scores for the reminder of the post-intervention phase. As shown on the achievement tests, the students achieved the scores that exceeded the criterion level on the generalization tests during the post-intervention phase and all four students maintained those scores for the reminder of the post-intervention period. Two weeks after the post-intervention phase, three of the four students successfully maintained their improved accuracy performance on the achievement and generalization tests during the maintenance phase. Student 4 took one achievement and one generalization test during the maintenance period. Although his single score could not demonstrate that his intervention gains on the accuracy performance were maintained over time on the achievement tests and generalization tests, his scores exceeded the criterion level. All four students were satisfied with the strategy in general.

Despite several limitations, the findings of this study have important implications for teachers and researchers. For example, the schema-based intervention, with its emphasis on conceptual understanding, helped students with learning disabilities not only acquire mathematical word problem solving skills but also maintain the taught skills. Therefore, teachers need to provide students with the strategy instruction in mathematical problem solving with required skills in an explicit way. Future research can include an investigation of whether the findings of the study can be generalized to more students with learning disabilities or other special education students in varied settings. In addition, a further investigation needs to be conducted to get both students and teachers' perspectives of the effectiveness and acceptability of the schema-based instruction to examine the feasibility of the schema-based intervention. Studies on the relationship between the schema-based intervention and the students' affect are also needed.

APPENDIX A:

CONTEXT OF THE RESEARCH



Purpose of the Study

The purpose of this study is to examine the effectiveness of schema-based intervention on the mathematical word problem-solving skills of middle school students with LD in grades 6-7.

Research Questions

- To what degree do students with LD in grades 6-7 improve in their performance on solving mathematical word problems after a schema-based intervention?
- To what degree do students with LD in grades 6-7 transfer the schema-based strategy to solving real world word problems developed by using the Mathematics Student Interest Inventory?
- To what degree do students with LD in grades 6-7 maintain the use of a schema based strategy for solving multiplication and division word problems?
- How will students with LD in grades 6-7 evaluate the effectiveness and acceptability of schema-based intervention?

Significance of the Study

- Provide students with real world problems developed by using the Mathematics Student Interest Inventory
- Explore the effects of schema-based intervention on the ability of students with learning difficulties to solve one-step multiplication and division word problems as the existing studies have done, but include only students with LD who do have goals in mathematics in their IEP in order to control their reading level.

APPENDIX B:
MATHEMATICS STUDENTS INTEREST INVENTORY

Student Name: Age/Grade Level: Period/Class:				
Things I Like to Do on My Own	Special Hobbies I Have	Things I Like to Learn About	Things I Like to Do With My Friends	Fun Things My Family Does

Note. Taken from “Mathematics Dynamic Assessment,” by D. H. Allsopp et al., 2008, *Teaching Exceptional Children*, *40*(3), p. 9.

APPENDIX C:
INTERVENTION RATING SCALE

Name: ______________________________ Date: ______________

PART I **Direction**. You learned to solve word problems using diagrams. Please circle the best answer for each item. Circle only one answer and do not skip any items	**STRONGLY DISAGREE**	**DISAGREE**	**UNSURE**	**AGREE**	**STRONGLY AGREE**
1. I enjoyed using the math word problem solving strategy used by the instructor.	**1**	**2**	**3**	**4**	**5**
2. I found the diagrams to be helpful in understanding and solving word problems.	**1**	**2**	**3**	**4**	**5**
3. I liked the word problem solving strategy because it helped me get better at solving math word problems.	**1**	**2**	**3**	**4**	**5**
4. I would recommend using this strategy with other students my age.	**1**	**2**	**3**	**4**	**5**
5. I am going to continue to use this strategy to solve word problems in my classroom.	**1**	**2**	**3**	**4**	**5**
6. I satisfied the overall process of the word problem solving strategy	**1**	**2**	**3**	**4**	**5**

Part II
Direction Write down what you liked during this intervention or want to suggest for the intervention.

Note. Adapted from Jitendra, Hoff, and Beck (1999)

APPENDIX D: STUDENTS' ACCURACY PERFORMANCE ON THE SCREENING TEST AND DURING THE BASELINE PHASE

Table D.1.
Student 1's Accuracy Performance on the Screening Test and during the Baseline Phase

Problem Type	Problem Subtype	PN	S	Baseline sessions 1	2	3	4	5	6	AT APS (%)	GT APS (%)	TOTAL APS (%)
MC	Compared unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	C	I	C	I	C	I	75	0	43
	Referent unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Scalar function unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
Vary	Unit value unknown	1	I	I	C	C	I	I	I	25	33	29
		2	I	I	I	I	C	C	I	25	33	29
	Either of two dimensions unknown	1	I	C	I	I	I	I	I	25	0	14
		2	C	C	I	I	I	I	I	50	0	29
Number of Correct			1	3	1	2	1	2	0			
Number of Problem Solved			10	10	10	10	10	10	10			
Test type			AT	AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. S = Screening Test. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table D.2.
Student 2's Accuracy Performance on the Screening Test and during the Baseline Phase

Proble m Type	Problem Subtype	PN	S	Baseline sessions						AT APS (%)	GT APS (%)	TOTAL APS (%)
				1	2	3	4	5	6			
MC	Compared unknown	1	I	I	I	I	I	C	C	25	33	29
		2	I	C	I	C	C	C	C	75	67	71
	Referent unknown	1	I	I	I	C	I	C	I	50	0	29
		2	I	I	I	I	I	I	I	0	0	0
	Scalar function unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
Vary	Unit value unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Either of two dimensions unknown	1	I	I	I	I	C	I	I	0	33	14
		2	I	I	I	C	I	I	I	25	0	14
Number of Correct			0	1	0	3	2	3	2			
Number of Problem Solved			10	10	10	10	10	10	10			
Test type			AT	AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. S = Screening Test. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table D.3.
Student 3's Accuracy Performance on the Screening Test and during the Baseline Phase

Problem Type	Problem Subtype	PN	S	Baseline sessions 1	2	3	4	5	6	AT APS (%)	GT APS (%)	TOTAL APS (%)
MC	Compared unknown	1	C	I	I	I	I	C	I	50	0	29
		2	I	I	I	C	I	C	I	50	0	29
	Referent unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Scalar function unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
Vary	Unit value unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Either of two dimensions unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	C	I	I	I	25	0	14
Number of Correct			1	0	0	2	0	2	0			
Number of Problem Solved			10	10	10	10	10	10	10			
Test type			AT	AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. S = Screening Test. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table D.4.
Student 4's Accuracy Performance on the Screening Test and during the Baseline Phase

Proble m Type	Problem Subtype	PN	S	Baseline sessions						AT APS (%)	GT APS (%)	TOTAL APS (%)
				1	2	3	4	5	6			
MC	Compared unknown	1	I	I	I	I	I	I	I	0	0	0
		2		I	I	I	I	I	I	0	0	0
	Referent unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Scalar function unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
Vary	Unit value unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
	Either of two dimensions unknown	1	I	I	I	I	I	I	I	0	0	0
		2	I	I	I	I	I	I	I	0	0	0
Number of Correct			0	0	0	0	0	0	0			
Number of Problem Solved			9	10	10	10	10	10	10			
Test type			AT	AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. S = Screening Test. MC = Multiplicative Compare. C = Correct. I = Incorrect.

APPENDIX E:
STUDENTS' ACCURACY PERFORMANCE DURING THE POST-INTERVENTION PHASE

Table E.1.
Student 1's Accuracy Performance during the Post-intervention Phase

Problem Type	Problem Subtype	PN	Post-intervention sessions 1	2	3	4	5	6	AT APS (%)	GT APS (%)	TOTAL APS (%)
MC	Compared unknown	1	C	C	C	C	C	C	100	100	100
		2	I	C	C	C	C	C	67	100	83
	Referent unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	C	100	100	100
	Scalar function unknown	1	C	C	I	C	C	C	67	100	83
		2	C	C	I	C	C	C	67	100	83
Vary	Unit value unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	C	100	100	100
	Either of two dimensions unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	C	100	100	100
Number of Correct			9	10	8	10	10	10			
Number of Problem Solved			10	10	10	10	10	10			
Test type			AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table E.2.
Student 2's Accuracy Performance during the Post-intervention Phase

Problem Type	Problem Subtype	PN	Post-intervention sessions						AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4	5	6			
MC	Compared unknown	1	C	C	C	C	C	C	100	100	100
		2	C	I	C	C	C	I	100	33	67
	Referent unknown	1	C	C	I	C	C	C	67	100	83
		2	C	C	C	C	C	C	100	100	100
	Scalar function unknown	1	C	C	I	I	C	C	67	67	67
		2	C	C	C	C	I	C	67	100	83
Vary	Unit value unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	I	100	67	83
	Either of two dimensions unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	I	C	C	100	67	83
Number of Correct			10	9	8	8	9	8			
Number of Problem Solved			10	10	10	10	10	10			
Test type			AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table E.3.
Student 3's Accuracy Performance during the Post-intervention Phase

Proble m Type	Problem Subtype	PN	Post-intervention sessions						AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4	5	6			
MC	Compared unknown	1	C	C	I	C	C	C	67	100	83
		2	I	I	C	I	I	C	33	33	33
	Referent unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	I	100	67	83
	Scalar function unknown	1	C	C	C	C	C	C	100	100	100
		2	I	C	C	I	C	C	67	67	67
Vary	Unit value unknown	1	C	I	C	C	C	C	100	67	83
		2	C	C	C	C	C	C	100	100	100
	Either of two dimensions unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	C	100	100	100
Number of Correct			8	8	9	8	9	9			
Number of Problem Solved			10	10	10	10	10	10			
Test type			AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table E.4.
Student 4's Accuracy Performance during the Post-intervention Phase

Problem Type	Problem Subtype	PN	Post-intervention sessions						AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4	5	6			
MC	Compared unknown	1	C	I	C	C	C	C	100	67	83
		2	C	C	C	I	C	C	100	67	83
	Referent unknown	1	C	C	C	C	C	C	100	100	100
		2	C	C	C	C	C	C	100	100	100
	Scalar function unknown	1	I	C	C	C	I	C	33	100	67
		2	I	C	I	I	C	C	33	67	50
Vary	Unit value unknown	1	C	C	C	I	C	C	100	67	83
		2	I	I	C	C	I	C	33	67	50
	Either of two dimensions unknown	1	C	I	I	C	C	C	67	67	67
		2	C	C	C	C	C	C	100	100	100
Number of Correct			7	7	8	7	8	10			
Number of Problem Solved			10	10	10	10	10	10			
Test type			AT	GT	AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

APPENDIX F:
STUDENTS' ACCURACY PERFORMANCE DURING THE MAINTENANCE PHASE

Table F.1.
Student 1's Accuracy Performance during the Maintenance Phase

Problem Type	Problem Subtype	PN	Post-intervention sessions				AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4			
MC	Compared unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
	Referent unknown	1	C	I	C	C	100	50	75
		2	C	C	C	C	100	100	100
	Scalar function unknown	1	C	C	C	C	100	100	100
		2	C	C	I	C	50	100	75
Vary	Unit value unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
	Either of two dimensions unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
Number of Correct			10	9	9	10			
Number of Problem Solved			10	10	10	10			
Test type			AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table F.2.
Student 2's Accuracy Performance during the Maintenance Phase

Proble m Type	Problem Subtype	PN	Post-intervention sessions				AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4			
MC	Compared unknown	1	I	C	C	C	50	100	75
		2	C	I	C	I	100	0	50
	Referent unknown	1	I	C	C	C	50	100	75
		2	C	C	C	C	100	100	100
	Scalar function unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
Vary	Unit value unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
	Either of two dimensions unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
Number of Correct			8	9	10	9			
Number of Problem Solved			10	10	10	10			
Test type			AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table F.3.
Student 3's Accuracy Performance during the Maintenance Phase

Proble m Type	Problem Subtype	PN	Post-intervention sessions				AT APS (%)	GT APS (%)	TOTAL APS (%)
			1	2	3	4			
MC	Compared unknown	1	I	C	C	C	50	100	75
		2	C	C	I	C	50	100	75
	Referent unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
	Scalar function unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
Vary	Unit value unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
	Either of two dimensions unknown	1	C	C	C	C	100	100	100
		2	C	C	C	C	100	100	100
Number of Correct			9	10	9	10			
Number of Problem Solved			10	10	10	10			
Test type			AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

Table F.4.
Student 4's Accuracy Performance during the Maintenance Phase

Problem Type	Problem Subtype	PN	Post-intervention sessions 1	2	3	4	AT APS (%)	GT APS (%)	TOTAL APS (%)
MC	Compared unknown	1	C	C			100	100	100
		2	C	C			100	100	100
	Referent unknown	1	I	C			0	100	50
		2	C	C			100	100	100
	Scalar function unknown	1	I	C			0	100	50
		2	C	C			100	100	100
Vary	Unit value unknown	1	C	C			100	100	100
		2	C	C			100	100	100
	Either of two dimensions unknown	1	C	C			100	100	100
		2	C	C			100	100	100
Number of Correct			8	10					
Number of Problem Solved			10	10					
Test type			AT	GT	AT	GT			

Note. APS = Accuracy Percentage Score. AT = Achievement Test. GT = Generalization Test. PN = Problem Number. MC = Multiplicative Compare. C = Correct. I = Incorrect.

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